Professional paper

CROalertNet – SYSTEM ARCHITECTURE AND PROPOSED MODULES

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Abstract: *This paper expands on the previously presented idea for a new information system – CROalertNet. CROalertNet is a multi-platform, multi-module information system designed to use mobile devices to assist civilians during crisis events and which is capable of maintaining a basic degree of functionality in offline mode, which is the expected state during a major crisis event. Our previous work described the need for such an information system and presented, in detail, the idea of a single module – a bomb shelter location mobile application. The previously presented module is a small part of the whole system and in this paper, we expand on the system by proposing a full module list and basic system architecture of the CROalertNet information system. A fully developed CROalertNet system would greatly enhance communication capabilities during crises and enable civilians access to vital information even when communication channels (such as mobile networks) break down or function in a reduced capacity due to network congestion.*

Keywords: *application, CROalertNet, information system, architecture, module, crisis management, mobile platform*

1. Introduction

The aim of this paper is to is to expand on the developmental idea of the CROalertNet application and platform, which is designed to improve the safety and awareness of citizens of the Republic of Croatia in the event of crisis situations. The original work was presented in 2024. during the Crisis Management Days conference (Filipović, Bralić, & Bralić, 2024). This previous work presented the general idea of using smart mobile devices, such as smart phones, to assist in crisis situations by providing vital information and other services without the usual data connection requirement. It also presented a single functionality of the proposed system, an offline bomb shelter locator. In this paper we expand on the idea of CROalertNet by proposing additional features and modules.

Crisis situations, whether natural or man-made, require a quick and effective response to minimize damage and save lives. The proposed platform aims to provide timely information that is crucial for proper preparation and response to such situations.

The most important part of the CROalertNet platform is the mobile application which assists users by providing vital information, such as emergency service and shelter location, in crisis situations. While similar applications already exist, they are heavily reliant on mobile network data. Mobile data can, due to unusually high mobile traffic, become unavailable in a crisis situation, (Hina, 2020) limiting the usability of these applications.

The mobile application component of the CROalertNet platform is specifically designed to maintain the maximum possible level of usability in a situation where the device is still functional, but the mobile (data) network is down due to congestion or infrastructure damage.

2. CROalertNet – platform architecture

The platform is designed to function as an online central repository with multiple end points providing data to various services, the most important of which is the CROalertNet mobile application. This application needs to maintain periodic contact with the central repository to receive updates while the mobile network functions normally. If the mobile network is disrupted for whatever reason, the mobile application reverts to using locally stored data. Further, as civilians and emergency service workers begin to gather in certain areas, such as shelters and emergency rally points, the mobile application can use near field communications (Al-Ofeishat & Al Rababah, 2012) and Wi-Fi connectivity (Mozaffariahrar, Theoleyre, & Menth, 2022) to share preloaded available data with other clients.

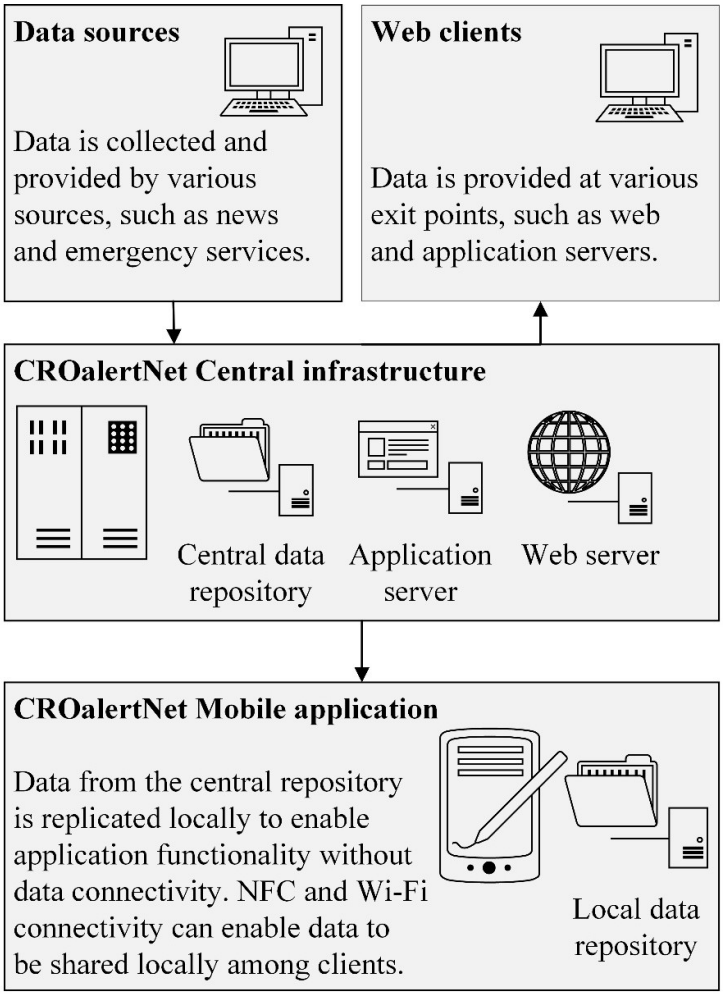

Figure 1 CROalertNet system organization

Figure 1 shows the main groups of CROalertNet infrastructure and the chief data flow between them. The data sources group includes various exterior information sources, such as Civil Protection Directorate sources, Ministry of Interior sources, Health ministry sources and others which can provide critical information during a crisis situation. These represent the main data source for the system. In addition to these exterior sources, an important data source are components of the CROalertNet system itself which are controlled by emergency workers, such as a version of the CROalertNet mobile application designed for emergency workers.

The Central infrastructure group receives this information, adapts and filters it as necessary, and provides it to the CROalertNet endpoints, which comprise of the remaining two groups, the Mobile application, and the Web clients and services. Other than funneling data, the Central infrastructure also provides a data repository service, which enables the distribution of existing data in case of data source failure (due to network or source failure) as well as historical data for later review and analysis.
The Web client's group includes CROalertNet web pages and public API services which distribute information without a specialized (mobile) application. This component of the system is not critical to CROalertNet system but the simplicity of its implementation (once other components are complete) justifies providing these information channels, which are otherwise widely available from other providers. CROalertNet will require a web presence even without such channels, to provide information on the system to potential users before they install the mobile application.
The third group consists of mobile applications. The primary role of these applications is to run on a held device and be able to distribute end information to the user during a crisis situation. The secondary roles of this software include ad-hoc networks of nearby users and the ability to push new information from a specialized application designed for emergency responder use. The most important feature of this group, which comprises the critical and unique part of the system, is its ability to maintain a high degree of functionality even when the mobile network is impaired due to congestion, a common occurrence during a crisis event (Hina, 2020), or even shut down due to communication infrastructure damage. This is achieved by implementing three important features:

- Local data storage which contains information which is vital in a crisis situation including emergency service and shelter locations, general information on emergency procedures such as first aid instructions and most recently available information (before communication congestion or breakdown) on the current crisis. Most modern mobile applications prefer to avoid local storage, moving everything to remote infrastructure, more commonly referred to as "cloud" storage and services. This approach has many advantages but renders the application unusable during a communication network breakdown. CROalertNet mitigates this risk by combining remote data sources with local storage.
- Specialized software designed to provide basic functionality of otherwise online dependant applications in offline mode. The best example of this behaviour is an offline navigation tool. Most modern navigation applications, such as Google maps (Google LLC, 2024) depend on mobile device data traffic being available. While Google maps can function without mobile device data traffic by using various satellite radionavigation systems such as GPS (Dixon, 1991), GLONASS (Revnivykh, Bolkunov, Serdyukov, & Montenbruck, 2017) and GNSS (Langley, Teunissen, & Montenbruck, 2017) these provide only the device longitude and latitude. The system is heavily reliant on data traffic to download maps, and in particular details on these maps. If the map of a local area was never downloaded, the system will not function. Additionally, the system will fail to locate specific locations which are not downloaded by default but rely on internet searches to provide an address. Such locations usually include shops, hospitality venues and similar but might also include crisis situation critical locations such as local hospitals, shelters and other emergency service locations which render the system less useful in situations without data traffic. CROalertNet can develop a specialized version of these applications, leveraging Google's publicly available services such the Location Services (Ibrahim & Mohsen, 2014) and Reverse Geocoding (Panasyuk, Yu, & Mehrotra, 2019) and combining them with locally stored data, including maps with emergency service and shelter locations, to provide full functionality (for the purpose of civilian safety and crisis management) during communication blackouts.
- Finally, the system can enable local communication by establishing ad-hoc networks using various near field communications (Al-Ofeishat & Al Rababah, 2012), such as Bluetooth (Sairam, Gunasekaran, & Redd, 2002), and the Wi-Fi protocol (Mozaffariahrar, Theoleyre, &

Menth, 2022). Such networks rely only on the communication capabilities of individual devices in proximity to each other, without reliance on any type of outside network infrastructure. These ad-hoc networks are well researched (Aneja & Gambhir, 2021) and have seen application in various situations, such as social networks (Zhang, Zhang, Xiong, Hsu, & Vasilakos, 2014). As civilians gather in emergency shelters or other hotspots CROalertNet can leverage these technologies to provide updated information even during a period of heavy network congestion. If a single device in an area manages to receive an update it can propagate information to other nearby devices. Further, during a full communication blackout these technologies will enable emergency workers to propagate information to nearby devices. Even though this information needs to be created by the emergency workers on site it still provides a useful ability to communicate with the local group of civilians. The functionality is similar to using a bull horn but allows persistent information, visual information, and possibly automatic translation. The basic functionality of such a network is displayed in Figure 2.

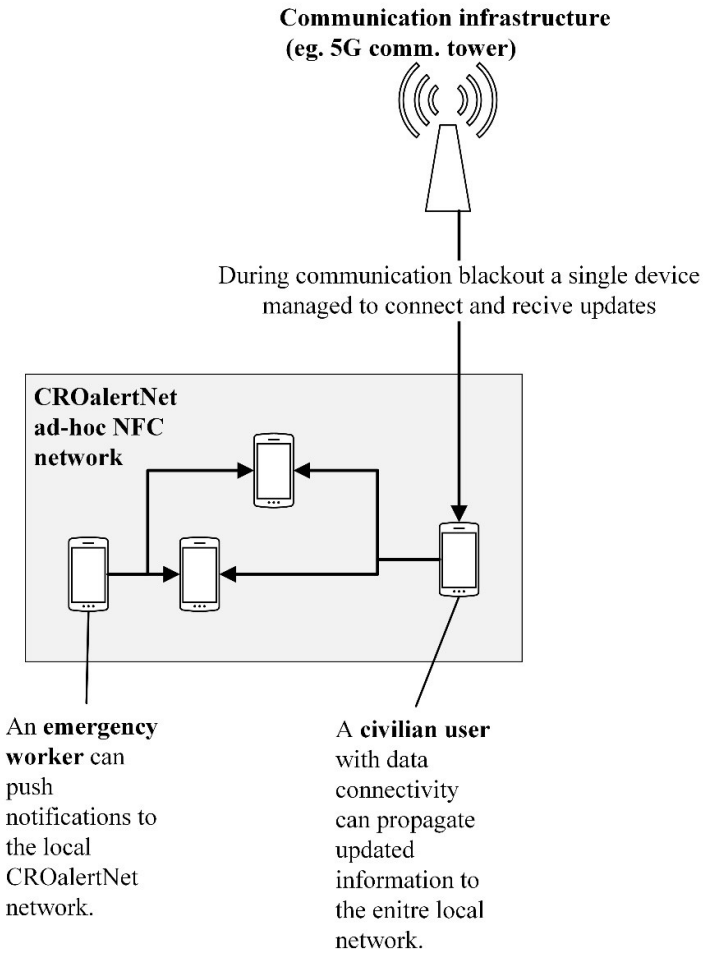

Figure 2 CROalertNet ad-hoc network

In regard to the functionalities of the system we propose four different modes of work of the application depending on mobile network and satellite radionavigation systems' availability. Table 1 provides an overview of these modes.

Table 1 CROalertNet modes of work

Mode of work	Functionality overview
Full mobile network connectivity	• Full features operational. • Real time two-way communication with the CROalertNet central infrastructure. • Fully functional location services.
Partial mobile network connectivity	• Partial features depend on locally stored data and NFC communications. • If the mobile network is congested new information can still be disseminated locally via NFC communication with those CROalertNet clients who managed to get through the congestion or from locally present emergency workers. • Location services depend on satellite radionavigation systems and preloaded data.
No mobile network connectivity	• Partial features depend on locally stored data and NFC communications. • New information is available only via NFC communications from locally present emergency workers. • Location services depend on satellite radionavigation systems and preloaded data.
No mobile connectivity and no satellite radionavigation systems	• Partial features depend on locally stored data and NFC communications. • New information is available only via NFC communications from locally present emergency workers. • Location services depend exclusively on preloaded data and provide a detailed passive map.

3. CROalertNet – mobile application variations

The CROalertNet platform is modular, both its central components and its mobile application, providing various modules to provide for a service tailored to individual groups. For example, a tourist and a local citizen might have a need for a different set of features and different information. A modular design also allows easier development and maintenance. In this chapter we list some of the proposed mobile application modules and features. A more detailed overview of the whole system, particularly its central infrastructure, is beyond the scope of this paper and requires a well-defined feature set for its end points, such as the mobile applications. Some of the proposed mobile application features are:

- Shelter map: a map of local shelters. This information is not always available on public services such as Google Maps (Google LLC, 2024) and even when it is available such services rely on both data traffic and location service functionality. The CROalertNet module can have shelter

information preloaded in local storage and can estimate the user's location based on the last available data or using purely satellite radionavigation systems. This module was explained in detail in the author's previous work (Filipović, Bralić, & Bralić, 2024).

- Fully passive maps: a highly detailed preloaded area map can be used even in a full communication and navigation infrastructure failure situation. While satellite radionavigation systems are not easy to damage their communications can be jammed or disabled (in a war crisis situation). In such a case a fully offline map with detailed street names is still useful but not readily available on normal location service systems. In this mode the map is the equivalent of a traditional paper map.
- Preloaded emergency information: the mobile application can locally store general emergency situation instructions, such as first aid, fire prevention, earthquake and air raid instructions and make them available without mobile data connectivity. This module provides a passive data source with easily accessible, locally stored data which is available during communication blackouts.
- Live updates: the mobile application can leverage NFC communications to enable information dissemination during partial or full communication blackouts. Last available data can be locally propagated by any CROalertNet device and new information can be provided by local emergency workers.
- New information for emergency services: assuming the communication network has not failed, CROalertNet can be used by civilians to provide information for emergency workers, similar to emergency phone numbers, such as 112 in the EU or 911 in the US. The system can easily transmit audio, visual, geolocation and textual information, similar to the Croatian Ministry of the Interior suspicious activity reporting mobile application (Croatian Ministry of the Interior, 2025).
- Emergency alarm: the mobile device can be used to provide auditory and visual alarms by using its loudspeaker and flashlight, as well as NFC communications to assist emergency workers in locating elderly or disabled civilians. Such a system can be put on alert status in an emergency situation and, where available, use other data sources, such as connected smart watch or fitness band devices to detect anomalous vital signs and automatically activate.
- Hot spot population numbers: NFC and normal mobile communications (if available) can be used by emergency workers to estimate the movement or number of civilians in a certain area, aiding in crisis situation management and location of civilians in jeopardy.
- NFC communications: the CROalertNet mobile application can be used to help a civilian group organise itself if emergency workers are not present on site. A basic group chat communication using NFC communications enables this.
- Specialized emergency worker application: such an application can assist in communication between emergency workers and services in addition to enabling one- or two-way communication with civilians. Additionally, the emergency worker application can assist in locating civilians in distress.
- Post crisis analysis: having a system such as CROalertNet, which can track the location and situation of civilians during a crisis situation, can simplify later analysis and possibly provide new insights enabling emergency services to better prepare for future crises.

4. Conclusion

This paper expands on our previous work (Filipović, Bralić & Bralić, 2024.) which described the general underlying idea of the CROalertNet platform and one of its modules (shelter location module) by providing a more detailed examination of the proposed system architecture and expanding on the feature list.

The CROalertNet platform is an emergency situation information distribution and assistance system specifically aimed at dealing with situations in which mobile networks fail due to network congestion or communication infrastructure damage.
A fully autonomous emergency information system, using NFC communications and offline data can aid civilians in distress and emergency services in crisis situations in many ways. However, most modern systems which try to achieve this rely on the communication infrastructure, a system which traditionally fails due to network congestion even during minor crisis events. An example of such a system is the Croatian SRUUK early warning and crisis management system (Civil Protection Directorate, 2023) which relies on SMS and mobile data traffic to disseminate information. While the goal of this system is early warning, meaning the time prior to the crisis event happening, during which mobile communications should be functional, the CROalertNet system builds upon this by providing functionality even after mobile communication breakdown. In addition, unlike SRUUK, the CROalertNet platform is capable of two-way communication and enables the creation of local ad-hoc networks which assist in crisis situation management.

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CROalertNet –ARHITEKTURA SUSTAVA I PREDLOŽENI MODULI

Sažetak: *Ovaj rad proširuje prethodno predstavljenu ideju novog informacijskog sustava – CROalertNet. CROalertNet je višeplatformski, modularni informacijski sustav dizajniran za pomoć civilima tijekom kriznih događaja upotrebom mobilnih uređaja i koji je sposoban održavati osnovni stupanj funkcionalnosti bez dostupnosti mobilnog podatkovnog prometa, što je očekivano stanje tijekom velikog kriznog događaja. U našem prethodnom radu opisali smo potrebu za takvim informacijskim sustavom i detaljno predstavili ideju jednog modula – mobilne aplikacije za lokaciju skloništa od bombi. Prethodno predstavljeni modul je mali dio cijelog sustava, a u ovom radu proširujemo sustav predlažući širi popis modula i osnovnu arhitekturu sustava informacijskog sustava CROalertNet. Potpuno razvijen CROalertNet sustav uvelike bi poboljšao komunikacijske mogućnosti tijekom kriza i omogućio civilima pristup vitalnim informacijama čak i kada komunikacijski kanali (poput mobilnih mreža) zbog zagušenja ili oštećenja mobilne mreže prestanu raditi ili rade smanjenim kapacitetom.*

Ključne riječi: *aplikacija, CROalertNet, informacijski sustav, arhitektura, modul, upravljanje krizama, mobilna platforma*