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A distributed man-machine Dispatching architecture for emergency operations based on 3GPP Mission Critical services

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ABSTRACT With the number of non-human devices expected to significantly overtake human users of LTE networks, it is no surprise that First Responders in Mission Critical operations will need to interact with an increasing number of unmanned devices, “bots” or drones. In the paper we propose the Mission Critical “bot” concept as an entity capable of gathering environmental/situational information and triggering certain automated actions without the need of human intervention. We prove that in certain circumstances these bots can help quickly resolve emergency situations and complement traditional centralized coordination from Dispatch Control Rooms. We explain how such “bots” relate and expand the 3GPP Mission Critical Communications architecture framework, considering different architectural approaches and complexity levels. Importantly, because First Responders must remain focused, hands-free and context-aware most of the time, we cover specifically the case where man-machine interaction is based on voice communication without having to use hands or look at a screen. It is hence of particular interest to convert “bot” interactions into audio information exchanged over push-to-talk communication services, be it through the cellular network or leveraging the 3GPP device-to-device capability. The paper is complemented with theoretical use cases as well as description and multimedia material of a prototype implementation of a concept emulator.

INDEX TERMS 3GPP, Control Room, C4I, D2D, Emergency Services, Fire, Fire brigades, Industry Applications, MCPTT, MCVideo, MCData, LTE, Mission Critical Services, PPDR, ProSe, Public Safety, Safety, UAV

I. INTRODUCTION AND RELATED WORK

Mission Critical (MC) operations in the civil domain comprise activities handled by so-called “First Responders” such as police officers, fire fighters, Search and Rescue, Medical Emergency support personnel, Civil Protection, … Not all activities carried out by such professionals imply Mission Critical nature, but under certain circumstances these professionals participate in activities where either citizens’ life or emergency personnel’s life is at stake.

MC operations heavily relay on Mission Critical Communications (MCC) systems. While public cellular mobile networks are intended to serve massive voice and data services with carrier-grade reliability, traditional MCC systems typically consist on highly redundant dedicated network infrastructure leveraging spectrum frequency bands specifically allocated for MCC. Importantly, some of the key requirements by First Responders for their communication systems include high reliability, instant delay (typical mouth-to-ear delay must not exceed 300ms) [1], group communications (required for emergency teams coordination) and strong support for Dispatch-managed operations. As an example, traditional MCC systems offer a set of interfaces to connect external Control Room or Dispatch Centers.

A Control Room environment typically consists of one or more Dispatch operators who may receive information from a number of different sources (e.g,: emergency communications, 911/112 incoming calls, location devices, video feeds from surveillance cameras, …). In turn, Dispatch operators make decisions based on available information,

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operational procedures and experience. Such decisions are communicated in the form of voice commands toward First Responders instructing, advising and providing information to coordinate how individuals and teams work together to handle an emergency situation in the field.

In general, in order to achieve the best possible coordination of emergency teams, MCC typically follow a top-down hierarchical approach where the First Responder acts under the command of the Dispatch operator who has a general perspective of the operational situation.

Over the last 15-20 years two main architectures have been deployed worldwide to support MCC, namely the ETSI TErrestrial Trunked RAdio (TETRA) [2] system and the US APCO Project 25 (P25) system [3], under the broad family of Professional Mobile Radio (PMR) technologies.

The communication paradigm between the First Responder and the Dispatch Operator in traditional MCC systems is depicted at a high level in Figure 1. Essentially, the First Responder will Detect, Report and Inform, while the Dispatcher will Instruct, Command and Coordinate.

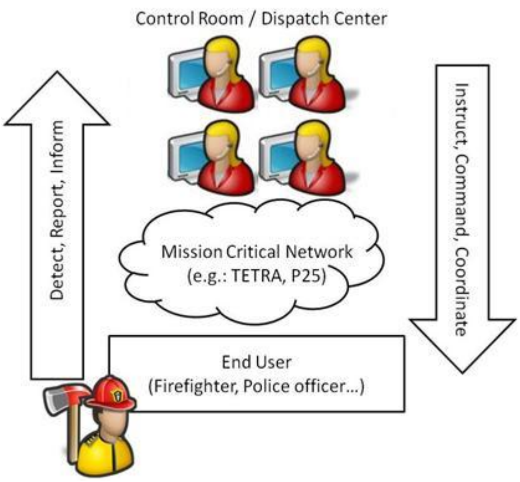

FIGURE 1. Top-down dispatching in Mission Critical operations.

In our research for related work we have identified efforts by the community in the areas of Control Rooms for MC operations [4][5], drone-assisted MC operations [6][7][8] and involvement of autonomous robots in MC operations [9][10], respectively.

When it comes to Control Rooms research we acknowledge that significant work has been devoted into areas such as the optimization of the decision-making process in traditional top-down Command and Control systems for Public Safety and Fire Fighting [4] or the optimization of the design of the Command and Control infrastructure itself [5], where the community actually acknowledges that excess of information processing by Control Room operators may degrade operational efficiency [11]. However, little discussion exists about the possibility to mitigate the issue through process automation or distributing the decision making process.

In relation to drone-assisted MC operations, the community has invested significant effort into defining the network-layer interaction, both from a device-to-device (D2D) [12] and Isolated E-UTRAN Operation for Public Safety (IOPS) [13] perspective where such drones mostly operate as coverage “extenders” [6] or local connectivity providers [7][8] among First Responders. However, little contribution has been made considering such drones capable of interacting with First Responders from an operational perspective.

Finally, [9][10] cover the involvement of mostly automated or remotely managed robots in Mission Critical operations with little interaction or coordination with the rest of human First Responders in the field.

Actually, it has been proven that even in cases where UAVs (Unmanned Air Vehicles) are deployed to capture on-the-field information, significant improvements are required in the decision-making process to reduce the time required to spread information and to perform decisions based on such information [26].

The novelty of our approach comes by combining three elements (semi-automated “bots”, distributed Dispatch functions and 3GPP MCC technologies) to deliver a new paradigm. Effectively, the MC Dispatch “bot” expands the “Control Room” concept among a set of human and robot entities that collaborate together to increase efficiency of MC operations and/or safety of First Responders. In such framework, such “bots” may not operate in a fully automated way but in a collaborative way with First Responders in-the-field. Furthermore, the “bot” concept that we propose does not restrict its area of activity as coverage extender/connectivity provider, rather in our proposal the “bots” ability to gather and process information enable them to deliver useful, timely information to First Responders through the most convenient and instant communication means available: voice.

In essence, in our approach the assumption is made that in the foreseeable future a significant fraction of MC operations will require on-the-field human intervention. We argue that First Responders may benefit from enriching traditional top-down Control Center coordination with MC-enabled “bots” in the form of drones or robots –that work in close coordination of humans– deployed to support and increase coordination, situational awareness and safety of First Responder crews.

In this paper we present a novel distributed man-machine Dispatching architecture for emergency operations based on the combination of 3GPP MCC services and “bots” capable of interacting with First Responders through man-machine communications. The rest of the paper is organized as follows: section 2 briefly describes the 3GPP MC Communication services architecture, section 3 outlines the “Control Room” and “Dispatching” concept and presents

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MC "bots" as a means to distribute the dispatching function. Sections 4 and 5 discuss the "bot" architecture from an internal and 3GPP MCC perspective respectively. Sections 6 and 7 present theoretical as well as real implementation experiences respectively. Finally, section 8 outlines the conclusions and future work.

II. 3GPP MISSION CRITICAL COMMUNICATION SERVICES ARCHITECTURAL OVERVIEW

Over time, the vision that cellular systems would be able to provide non-mission critical group communication capabilities materialized first in the specification of the Open Mobile Alliance Push-to-Talk over Cellular service, presented by the authors in [14]. Over the last five years, the vision that 3GPP-based systems will eventually reach the capability of replacing TETRA and P25 systems has been growing, eventually reaching the approval of the so-called Mission Critical Push-to-Talk (MCPTT) enabler specification in June 2016 3GPP Release-13 [15]. Such work is currently being expanded with new MCC work items devoted to enhance MCPTT and the definition of the Mission Critical Data (MCData) [16] and Mission Critical Video [17] (MCVideo) enablers to be completed during 3GPP Release-14 and beyond [18].

The following diagram provides a high level overview of the 3GPP MCC services architecture with focus on the MCPTT service.

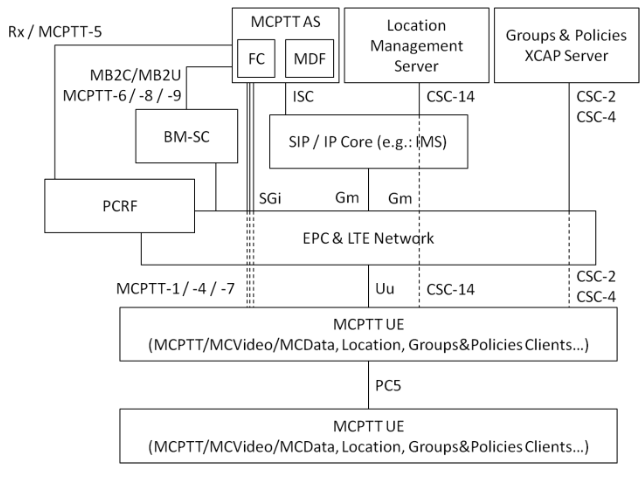

FIGURE 2. High level 3GPP MCC architecture.

Note that MCPTT comprises a set of architectural concepts from core Long-Term Evolution (LTE) / Evolved Packet Core (EPC) [19], MCPTT [20], 3GPP Proximity-based services (ProSe) [21] as well as the Common Services Core (CSC) for MCC services [22]. Figure 2 summarizes some of the key concepts, which are described as follows:

- The MCPTT Application Server (MCPTT AS) is in charge of delivering a walkie-talkie-like half duplex group voice communication service, and comprises two important functions: Floor Control and Media Distribution Function. In addition it contains all the service logic and acts as a Back-to-Back User Agent (B2BUA) from the signaling perspective.

- The MCPTT AS will interface the Policy and Charging Rules Function (PCRF) through the DIAMETER-based Rx interface. This interface lets the MCPTT AS push policies and inform the network about bandwidth/delay/loss tolerance and emergency status of a given media stream. The PCRF will use this information to determine flow priority in the EPC/LTE network.

- The EPC and LTE comprise the 4G core and Radio Access Network (RAN) respectively.

- The Broadcast/Multicast Service Center (BM-SC) allows the MCPTT AS to stream media through multicast bearers over the LTE RAN. This mechanism represents the combination of the MCPTT and the evolved Multimedia Broadcast and Multicast Service (eMBMS), which can help greatly enhance service performance and avoid congestion.

- The Location Management Server (LMS) and the Groups & Policies Server provide service to all MCC services (PTT, Video, Data). The LMS tracks location of all users while the Groups & Policies server stores XML Configuration Access Protocol (XCAP) documents which are used to store group and policies information for MCC services. Other common services such as Identity Management Server or Key Management Server are not displayed for the sake of simplicity.

In general the above architecture can be generalized to Mission Critical Data and Mission Critical Video by replacing the MCPTT AS with the corresponding MCVideo/MCData AS [17][16] respectively.

Finally, and importantly for the sake of our discussion, MCPTT, MCData and MCVideo also incorporate a D2D interface (PC5) that allows User Equipment (UE) to establish direct UE-to-UE connectivity without the need of LTE RAN coverage. This type of interface is inherited as a requirement from legacy MCC systems such as TETRA or P25, and intensively used by certain types of First Responders [12].

For the sake of our discussion, an MCPTT Dispatch "bot" or the MCPTT Dispatcher operating from a control room are a special type of MCPTT UE.

III. DISTRIBUTING THE CONTROL ROOM DISPATCH FUNCTION IN THE 3GPP MCC FRAMEWORK

Importantly, MCPTT not only will allow for the migration of the traditional voice-centric service delivered by P25 and TETRA systems (instant, team-focused, Dispatch-managed voice communications). Beyond the pure voice service, 3GPP MCC will enable a broad new range of services, which now become possible by leveraging IP technologies and mobile broadband capabilities that are not feasible in traditional narrowband PMR technologies.

Among other features, capabilities that will become available to First Responders include sending and receiving video feeds, remotely managing and exchanging information with LTE drones or "bots", remotely accessing Public Safety databases, triggering alerts, receiving situational awareness information from multiple sources and sharing, updating or displaying location information about users and devices.

In such framework the amount of relevant information available in real-time to multiple stakeholders (end users, support personnel, Dispatch users, supervisors…) will grow dramatically. Such information (e.g.: where are the team members, what are they seeing, how temperature is increasing around a firefighters team, what is the heart rate of the police officer, …) may be used to greatly enhance the decision-making process in the scope of emergency situations.

On the other hand, such substantial increase in information availability will surely lead to a dramatic shift in how emergency information is processed, managed, and acted upon. Effectively, small data and big data processing capabilities will be key in enhancing the human decision-making process based on rich, reliable and pre-processed information.

In this environment the authors envisage also a shift into how the traditional command-response, hierarchical, human-to-human interaction between First Responders and Dispatchers will evolve. Effectively, the current paper proposes that the traditional Dispatcher role may be split among a number of human and non-human entities that will spread and collaborate seamlessly through the whole MCC system.

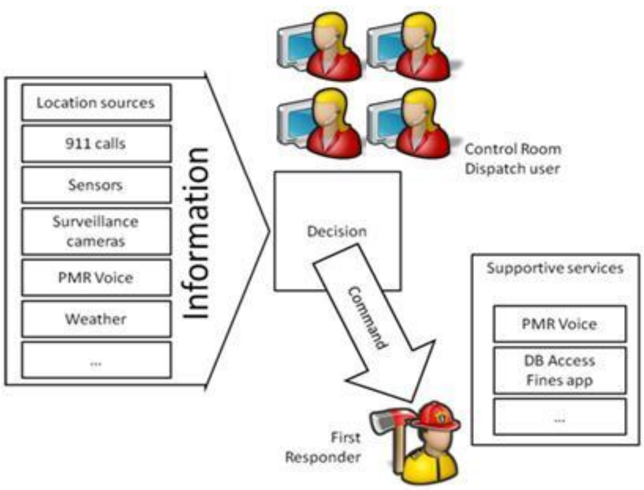

FIGURE 3. **Decision-making process in hierarchical dispatching.**

In the future, human Dispatch users will benefit from the collaboration with one or more non-human Dispatch "bots". Dispatch "bots" can act upon received and processed data. Furthermore, for certain types of interactions, "bots" can even proactively coordinate First Responders without the need of an explicit human decision by the Dispatcher in the Control Room environment. Of course, such non-human actions will only be issued in specific cases when the non-human Dispatch "bot" has been pre-programmed to perform automated decisions that are safe to be handled without direct human intervention.

Figure 3 presents the architecture that depicts the traditional Dispatch-managed paradigm in a greater degree of detail.

As depicted in Figure 3, Traditional Dispatching has been heavily based on three main pillars, namely: different types of voice communications (including TETRA and P25 systems), some location capabilities displayed on a Geographic Information System (GIS) map and, potentially, some video integration capability with surveillance cameras. All this information is displayed in large control room environments with dozens of large displays and dozens of Dispatch operators who try to make the most, through empirically developed processes, of the available information in tutoring and helping personnel in the field.

In a traditional MC scenario all events and information must be received by the Dispatcher, understood and voiced back to first responder teams. This approach has several drawbacks:

- The central human Dispatch operator becomes a bottleneck of the operation, which may impact speed of reaction, safety and effectiveness of the whole team [11].
- Relative importance and relevance of each individual information item is subject to judgement by the central Dispatch operator.
- Having to cope with specific items affecting just one or a very few users involved in an operation may unnecessarily occupy resources that might be useful for the coordination of the whole team or operation.

It must be noted that the above conclusions should be weighted with the fact that in large operations and complex environments, the "command chain" concept already provides a certain degree of distribution and shared responsibility among the different managers involved in the operation. Effectively, tactical control centers, on-the-field commanders, team leaders, supervisors and observers may help in implementing a relatively coordinated decision-making process where not all actions depend on one and only one Dispatch operator. However, the process is generally strictly hierarchical, and it has already been proven that as complexity increases in terms of the amount of information that a human has to process, effectiveness of the coordination activity decreases [11] and the convenience to automate certain tasks increases [23].

When we bring in the MC Dispatch "bot" concept into the picture the above situation can be enhanced significantly. Effectively, the Dispatch "bot" could work in close coordination with the isolated first responder it is providing support to. The "bot" can be pre-programmed to gather, consume and process certain types of information and trigger events based on such information.

Importantly, it is quite common that first responders are involved in tasks that require full attention, hands free

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operation and physical activity. This means that, as opposed to many everyday situations by other types of users, audio communications become fundamental to support first responders' activity. Effectively, a fire fighter, a police or paramedical officer may not be able to look at a smartphone screen or computer monitor in the middle of the heat of a real emergency operation. This is when good old, reliable, instant voice, walkie-talkie-like really can become the difference between success and a dangerous situation.

In such environment, being able to distill the "core" of useful and valuable information "pills", based on real facts, to a first responder can help save lives, speed resolution times and improve overall efficiency. In this framework, MC Dispatch "bots" come into play.

Figure 4 depicts the MC Dispatch "bot" concept, where the Dispatch function becomes distributed between human and non-human actors, which may provide assistance, instructions, informational awareness and commands.

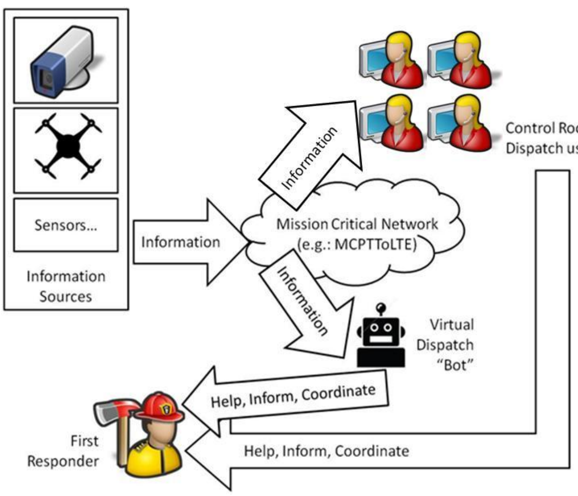

FIGURE 4. The MC Dispatch "bot" concept.

The virtual Dispatch "bot" depicted in Figure 4 represents the fact that it is today possible to gather significant amounts of information, process it and deliver to human recipients in a human-understandable format that prevents the end user from having to grasp raw data or invest significant time in simply understanding such amount of non-processed, disperse, unconnected data from different sources.

The virtual Dispatch "bot" is meant to work in coordination with the end user (the First Responder) as well as the human central Dispatch user. With such approach the Dispatch concept becomes "distributed", always under the command and supervision of the central human Dispatch user.

The benefits of this approach include:

- Reduce decision times, particularly in cases when certain decisions are obvious from an operational perspective but the First Responder involved may not have the perspective to take it and the Control Room Dispatch operator may not have the information required to make it.
- Ensure that all key information required to work effectively is available and presented in the right format at the right time to First Responders.
- Increase real as well as perceived safety by First Responders in the field.
- Ensure that critical information is delivered continuously toward the Critical Control Room Dispatcher.

We will develop the MC Dispatch "bot" concept forward in the following areas: a) Describe a sample high level architecture of the MC Dispatch "bot" concept and the data collection functionality, b) What type of information may be collected and processed by the Dispatch "bot", c) In what format the Dispatch "bot" may deliver the information and be helpful to the First Responder, and d) How the Dispatch "bot" concept may fit into the MCPTT architecture. Finally we will present a sample scenario where some of the outlined concepts are combined together to deliver added value to the First Responder and the Dispatch center.

IV. HIGH LEVEL INTERNAL "BOT" ARCHITECTURE

First, Figure 5 contains a sample high level architecture of the MCPTT Dispatch "bot" concept.

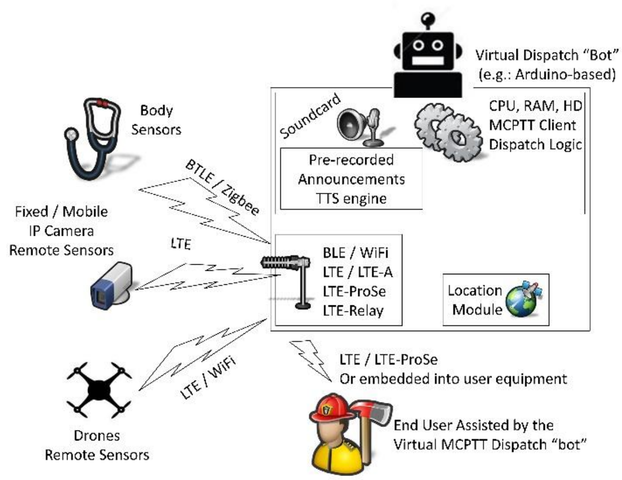

FIGURE 5. Proposed high level internal "bot" architecture.

The MCPTT "bot" may be based on any regular board including OpenSource HW platforms such as Arduino or Raspberry Pi. The "bot" itself may contain multiple RAN capabilities in order to retrieve diverse information sources. As an example:

- Information from certain proximity sensors can be captured through Bluetooth or ZigBee interfaces if available. This may include sensors attached to the clothes of a fire fighter or police officer, proximity beacons,…
- Wireless fixed and mobile camera video streams may be received over LTE.

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- Connection to other devices (e.g.: robots, drones, remote sensors, …) may be achieved through LTE or WiFi. Actually, a drone or UAV may implement the "bot" functionality as well.

- Connectivity with MCPTT users and the MCPTT infrastructure will be based on the LTE network itself. In turn, the "bot" may contain additional capabilities such as MCPTT ProSe [12] which allow the MCPTT "bot" to communicate with a user in the surroundings in case the network infrastructure is not available.

- A sound card capable of generating a set of audio announcements and notifications, as well as recording incoming audio communications through MCPTT channels.

The "bot" system will be complemented by a location module and the central processing engine, which on top of the underlying CPU, RAM and HD/SD it will run the MCPTT client logic (the one that allows communication with the MCPTT service and users) as well as the "Dispatching" logic built into the system.

V. DEPLOYING DISPATCH "BOTS" IN A 3GPP MCC ARCHITECTURE

In this section we review the architecture of the Dispatch "bot" concept from the 3GPP MCC perspective. We have split the evaluation into four layers, as described below. Figure 6 shows the architectural framework.

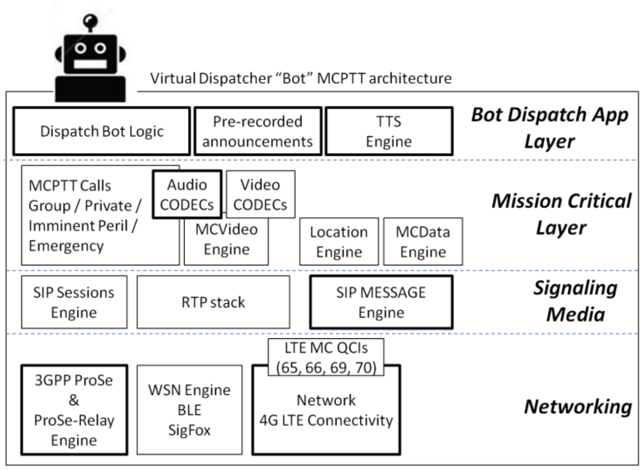

FIGURE 6. The MC "bot" in the 3GPP MCC architectural framework.

The application layer contains all the necessary logic as well as the elements required for the man-machine interaction, which may include a set of pre-recorded announcements or a text-to-speech engine that can be plugged into MC communications with the end user or the team the "bot" is providing support to.

On the MC layer three main functions may be present:

- An MCData engine can be used to exchange text, charts or pictures with an MCData application at the UE of one or more First Responders. As an example, data retrieved (e.g.: sensed) from the environment can be pushed to the relevant UEs interested in receiving such information. This delivery mechanism can be used mostly for non-intrusive non-urgent interaction, by providing information that complements the core operation of the team.

- An MCPTT engine. This can be used to deliver instant, real-time information to a user or a team. It may be based on triggers (time, location, sensed information) and it may be comprised of a combination of pre-recorded announcements and/or text-to-speech composed audio. MCPTT media can be played in the speaker of the user's device. Importantly, when audio information is delivered over MCPTT the listening user can freely use his hands without the need to pick up the device (as opposed to most MCVideo or MCData interactions).

- An MCVideo engine. Additionally, the "bot" may decide to stream video to a group or to the Dispatch Center in order to provide enhanced situational awareness (e.g.: a flying drone may stream video to a team of firefighters).

The signaling/media layer generally comprises the Real-time Transport Protocol (RTP) used to carry encoded audio or video related to MCPTT and MCVideo sessions. The Session Initiation Protocol (SIP) is used as the main signaling protocol by 3GPP Mission Critical services.

Note that, depending on the purpose, budget and capabilities, a given "bot" implementation may comprise one or more MC services, namely MCPTT, MCData or MCVideo, two, or all of them.

As a specific case of the MCData scenario the "bot" may include a location module capable of reporting location to one or more users as well as to the central Control Room.

Interestingly, many MCData and Location use cases can be implemented on top of the simple SIP MESSAGE transaction. Effectively, delivery of text messages, location coordinates (encoded in XML payload), file sharing URLs or status reports can easily be carried over the atomic SIP MESSAGE transaction based on MCData. This opens up the opportunity for developing a simplified "bot" without audio or video capabilities and running a trimmed down SIP stack, but able to report significant information both from Control Center to First Responders and reverse. Some of the functions required to implement a "simplified" bot are depicted in bold boxes in figure 6.

Note that the "bot" may have different types of form factors. From bodyworn equipment that connects to the UE to a specific SW or HW module attached to the device. It is of particular interest the case of Unmanned Aerial Vehicles (UAV) that may have simultaneous visibility of the end user(s) they are supporting to as well as connectivity to the core LTE network at the same time. When considering the MC Dispatch bot concept from a 3GPP MCC perspective we can present different example configurations as depicted in Figure 7.

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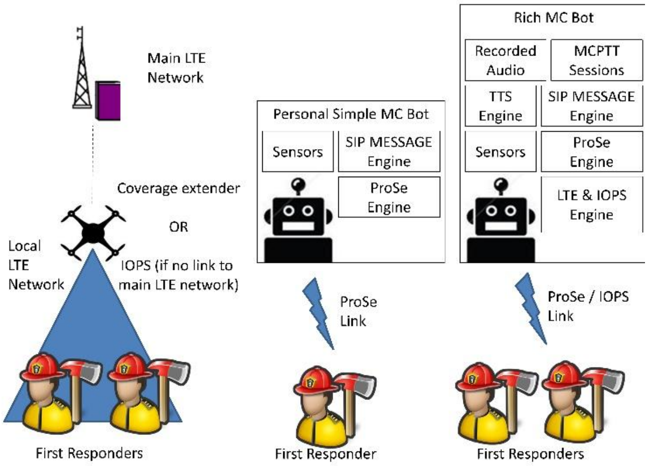

FIGURE 7. Example MC Dispatch bot configurations from 3GPP MCC perspective.

a) A first configuration covered elsewhere is usage of UAVs as LTE network coverage extenders or as providers of group communications to isolated teams [13][6][7][8]. In this regard it is of particular interest the case in which the "bot" can offer a hotspot of LTE coverage in a remote area, thus potentially serving a group of MCPTT users and allowing them to communicate efficiently regardless of the connectivity to the central network. 3GPP has standardized this scenario under the so-called Isolated Operations for Public Safety (IOPS), in which essentially a node (e.g.: the "bot" itself) can implement the whole RAN+EPC function and deliver one or more MC services in a local area [13]. We do not consider these as MC Dispatch "bots" as described in this paper because there is no application level logic and no reacting based on sensor information, but it is a powerful baseline scenario on top of which additional MC Dispatch "bot" functionality can be added.

b) Informative MC Dispatch "bot". This could consist on a simple "bot" with three main capabilities a) Sensors, b) A MCData SIP MESSAGE engine, and c) Connectivity to the end user UE (e.g.: Bluetooth, 3GPP ProSe, …). This bot provides supportive information that is sent to the UE and displayed to the user. It does not provide coverage extension and it does not send TTS audio messages (even though information sent over MCData could be played back locally by the UE through its own TTS engine).

c) Rich MC Dispatch "bot". In this case, in addition to the coverage / relay services mentioned in a), the bot may provide information to one or more First Responders by using its TTS engine connected to an MCPTT group communication. This group communication can be delivered to a team of First Responders in the field through a ProSe bearer.

Note that there may be valid use cases in which even if a UAV acting as a MC Dispatch "bot" keeps a ProSe link toward First Responders, it keeps an independent LTE link to the core Control Room, without acting as a relay. With this approach the "bot" may provide to the Control Room some critical information (e.g.: location of the team to keep them safe) while avoiding congestion on the LTE uplink (if it would relay all ProSe MCPTT communications) and saving its own limited battery resources.

VI. APPLICATION SCENARIOS

In order to understand how the architecture depicted in the previous section may be applied practically, in this section we describe some application scenarios, namely a fire brigade case and a police scenario. While these scenarios are provided for example purposes to showcase how the MC Dispatch "bot" can be applied and how it may fit into the 3GPP MCPTT architecture, the concept and architecture are of general application and other example alternative scenarios may involve MCC for Air Transport Industry (ATI), Search and Rescue operations or Business Critical communications in Industry where the Dispatch "bot" logic may be related to industrial sensors processes.

A. APPLYING DISPATCH "BOT" INTO A FIRE BRIGADE SCENARIO

In this case the scenario is as follows: a fire fighter is operating in the forest. He carries a belt that senses a number of human parameters such as blood pressure, skin temperature, heart rate, … As an isolated fire fighter he is supported by a drone that measures air temperature in the vicinity of the fire, concentration of dangerous gases (e.g.: NO, CO, CO2, ...). The advanced Command Center has pointed a Global Positioning System (GPS) coordinates where the next water delivery by a water tanker plane will be performed. The Estimated Time of Arrival (ETA) of the water tanker plane is 9 minutes from now. The fire fighter is 300 meters from the delivery point and 400 meters from the closest and safest team.

In the fire fighter scenario the supportive drone carries a small "bot" application with LTE connectivity that links him both to the fire fighter as well as the central Command Center. The drone detects that ambient temperature and gas concentration has reached high levels. Fire fighter skin temperature and heart rate indicate that the user is tired and quite close to the area where the next air water drop will happen. The Dispatch "bot" app sends a voice warning message to the fire fighter "*Next water drop is expected in 9 minutes. You are in an unsafe area. The closest support team is 400 meters to the East. You should depart now*". This message is shared instantly through the radio loudspeaker of the fire fighter as well as in a monitoring room back in the central Control Room. Support personnel supervise this message to confirm that this is a safe decision. The fire fighter confirms this order and safely joins his colleagues in time to watch how the air water drop significantly lowers the virulence of the forest fire.

Figure 8 highlights a more detailed scenario of the fire fighter MCPTT "bot" flow.

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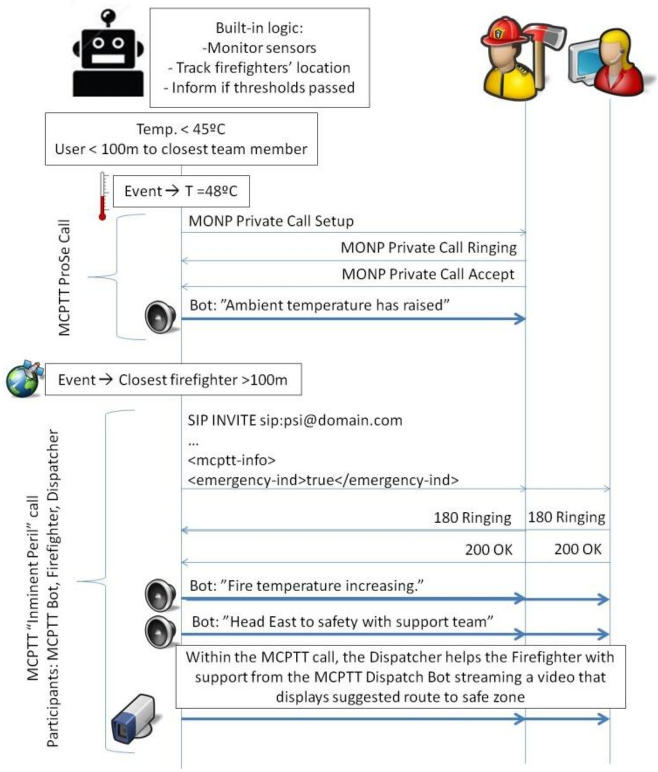

FIGURE 8. Example Dispatch "bot" firefighter scenario.

Note some of the features highlighted in the diagram:

- The "bot" may participate in different types of MCPTT sessions with different priority levels depending on the trigger point.

- The first flow depicts a direct mode call when the bot warns the firefighter that ambient temperature is rising. In this case the MCPTT Off-Network Protocol (MONP) [15][20] is used to setup a direct call over the 3GPP Proximity Services (ProSe) bearer [21]. This allows the "bot" and the user being supported to stay permanently in touch without occupying network and channel resources for the rest of the brigade.

- Upon crossing certain threshold the "bot" decides to start a new MCPTT "imminent peril" call involving the Dispatch Control Room operator. This is a group call run over the LTE network (since Dispatch-firefighter-bot communication is required). In particular, as highlighted in the flow, the "bot" sets the XML <emergency-indicator> element to "true" in the body of the SIP INVITE message to highlight that potential death or injury is possible.

This will naturally increase the level of alert as these calls are managed with special priority by the network and the MCPTT system, as well as displayed with additional visual and acoustic alerts in the control room. Imminent Peril calls are defined by 3GPP MCPTT as those were an emergency has not declared but it is likely and immediate unless urgent action is carried out [1].

- Eventually, the combination of the "bot" capabilities and the implementation of bot-assisted operational procedures may help bring the firefighter to the safe zone in a quicker and safer way than if pure human hierarchical communication would have been in place.

B. APPLYING DISPATCH "BOTS" INTO A POLICE SCENARIO

A police officer is engaged in an operation in an urban area. He is about to enter a bank branch where a theft has just been reported. An automated drone is overflying the area. Through its built in thermal cameras it detects human presence (three people) in the room beside the police officer. The overall system reports that additional reinforcements are about to reach the area in 2 minutes.

In the police scenario, the police officer's smartphone carries a built in MC Dispatch "bot". This "bot" is connected to the surveillance drone. When the "bot" receives information that human presence has been detected through thermal cameras it will issue a warning voice message that will be sent to the police officer: "*Human presence detected in the building. You are outnumbered. Reinforcements ETA 2 minutes*". The police officer will reach a safe area. When reinforcements arrive the burglars will surrender and the theft will be resolved without any major incidence. Voice messages are exchanged through earpieces instead of loudspeaker to avoid alerting the thieves.

In a nutshell, the scenarios depicted above showcase how the MC Dispatcher "bots" can improve safety of First Responders and automate some on-the-field decisions to improve efficiency of MC operations. In particular we can list some of the features and benefits of this approach:

- "bots" can be pre-loaded with programs adapted to the type of operations (e.g.: fire brigades, police operation, covert ops, counter terrorist, natural disaster, …).

- By leveraging 3GPP ProSe, Mission Critical "bots" would almost never lose connectivity to the end user they are providing support to. Hence, they could provide supportive assistance, information and safety even in cases when the end user has lost connectivity to the main site. Additionally, in certain circumstances (e.g.: UAVs used as "bots") the "bot" itself can have connectivity to the central site, thus enhancing the safety of the end user.

- "Bots" could be programmed with waypoints, trigger points, pre-recorded messages and actions that can easily be converted into audio messages voiced to end users -in some cases, using Text-to-speech (TTS) technology. Hence, the "bot" would communicate to the end user through the most convenient, least intrusive, most instant and most natural interaction mechanism, expected and widely used by emergency users.

- All "bot" communications and actions could be monitored from a back office environment in order to track the appropriateness of "bot" decisions, re-program or disable them in real-time (e.g.: in case that a wrong decision has been made) and develop a self-trained, continuous improvement procedure to enhance the behavior in future operations.

- A set of priorities could be defined, so that high priority or emergency communications triggered by human users or from the central Dispatch user, may take precedence over the "bot" communications, when needed. This would ensure that the first responder never loses communication with his human "counterpart", the human Control Room Dispatch operator. This will ensure that "bots" mechanisms and communications are only used in a supportive, complementary way, so that the traditional "command chain" is respected, thus ensuring full human control in all times.

VII. EXAMPLE REAL IMPLEMENTATION

In addition to the theoretical scenarios depicted above we have also implemented a use case in a real MCPTT implementation combining several of the concepts outlined in the paper.

For the sake of example purposes we have implemented a use case where the "bot" concept runs in the UE of the end user. Note however that this example use case can easily be generalized to an external "bot" o a UAV running some support "bot" functionality.

In this scenario the following items from our proposal are put together:

a) Enriching MCPTT communications with sensor information and machine communication.

b) Combining MCPTT communications and MCData/Location function.

c) Combining automated actions and centralized Control Room coordination.

The scenario is based on the Genaker MCPTT [24] implementation and runs on a professional LTE MCPTT UE. The scenario description can be watched in the referenced URL [25].

In this scenario a user that is performing a potentially risky task is running a UE that combines an MCPTT application and a man-down detection system. Man-down detection systems generally form part of the "Lone Worker Protection" (LWP) family of solutions, used in Industry and Oil&Gas sector in particular. The idea of man-down/LWP systems is to provide workers that perform their duties alone with a mechanism that detects when they fall down and may need medical assistance. LWP/Man-down systems typically consider three levels of emergency: "green" (the user is moving), "yellow" (a shock or absence of movement has been detected, and the user is not reporting he is safe) and "red" (the user has not reacted to the "yellow" state, immediate assistance is required).

The flow of this use case is depicted in Figure 9 and described below.

In our case when the user is about to start a potentially risky activity it will start the man-down-detection module. The man-down detection module is configured so that if the device remains stopped for more than 30 threshold it will a) Play a local announcement to the end user to request that he confirms he is safe, b) If the end user does not react, the man-down module will c) Report the location of the UE to the MC Location Service, and d) trigger an MCPTT *"Imminent Peril"* call.

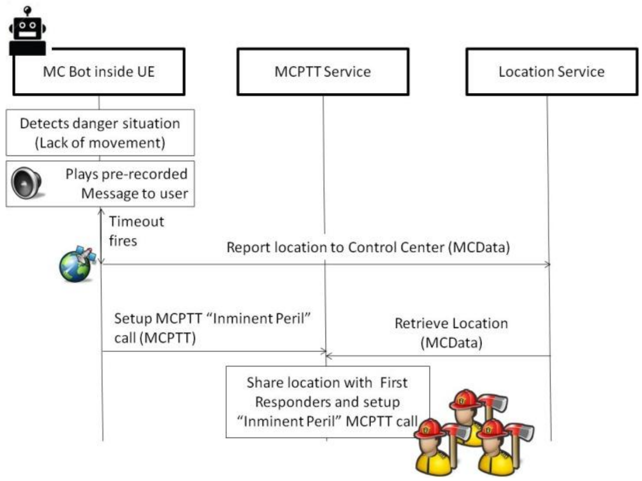

FIGURE 9. Man-down, MCData and MCPTT implementation flow.

When the MCPTT service receives the *"Imminent Peril"* call it will automatically retrieve location of the UE, report it to the Control Center and trigger an *"Imminent Peril"* call involving the Control Center Dispatch user as well as the pre-defined set of First Responders in charge of the search and rescue operation. Because the call is triggered automatically and because the location of the UE is reported instantly, chances of success of the rescue operation are maximized.

Note that traditional LWP systems may trigger a phone call or SMS sending to a predefined number. The benefits of our connection of the man-down MC "bot" to an MCPTT Imminent Peril call are obvious:

- Minimized detection-to-action time. In our scenario, once the "red" situation is detected (device static and no user reaction) the call is immediately setup. By using MCPTT no call setup and no alerting tone is required, but the call is connected instantly.

- Instant location report. In our scenario the MCData engine of the simulated MC Dispatch "bot" reports the location of the user in trouble while setting up the call, hence user location is available while the call is being setup.

- Instant support from a team of First Responders. As opposed to traditional voice calls and SMS, group communication is the natural choice in MCPTT. Hence, in such situation the "Imminent Peril" call may connect not only the Control Room Dispatch user but a team of the closest First Responders to the incident, hence ensuring that a team is put into operation as early as possible once the emergency is detected.

In summary, if we take T=0 as the time the device stops moving, the "lack of movement" situation is detected in t0+30s and a warning message is played to the user, the "imminent peril" call to inform the dispatcher and support team is established within t0+40s and the Dispatcher is fed with the location of the user in trouble within t0+42s. While the exact timing, triggers and configuration of the Dispatch "bot" will have to be adapted to handle real world scenarios (since it is important not to trigger "false positive" emergency calls) the achieved results may help reduce data-to-decision time by orders of magnitude when compared with traditional centralized dispatching operation [11][26].

As the reader can notice, possibilities offered by combining MC services (MCPTT, MCVideo, MCData, Location, …) with sensor systems, drones and UAVs, and the combination of LTE RAN and peer-to-peer ProSe connectivity are endless.

VIII. CONCLUSIONS AND FUTURE WORK

In this paper we have proposed the concept of Mission Critical Dispatch "bots". These are entities capable of gathering environmental/situational information and triggering certain automated actions without the need of human intervention. We have proven that in certain circumstances these "bots" can help to handle emergency situations in a more efficient way by distributing the traditionally centralized Dispatch role. We have explained how such "bots" can relate to the 3GPP architecture for Mission Critical services, considering different architectural approaches and complexity levels. Importantly, because First Responders must operate hands-free most of the time it is of particular interest to convert "bot" interactions into audio information exchanged over MCPTT communication services, be it through the LTE network or leveraging the 3GPP device-to-device capability. We have described two theoretical use cases related to our proposal and, finally, we have shown a real implementation of the concept that combines pre-recorded audio, automated triggers, Location services and MCPTT communications.

The authors are currently investigating the evolution of the concept when bringing MCVideo and eMBMS into the picture.

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