IMS Packet Switched Emergency Communications & ESInet Interconnection

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Executive Summary

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With the shutdown of 2G/3G networks across the world, emergency communications must migrate to 4G/5G networks which are exclusively based on packet-switched technologies. IMS provides the IP architectural framework to enable multimedia emergency communications services over IP networks, including those services mandated by EU legislation, such as NG eCall, Real time text and Total Conversation.

It is necessary to establish an appropriate infrastructure to facilitate these multimedia emergency communication services - an Emergency Service IP Network (ESINet). This document explains the need for, and benefits of an ESINet and ESINet peering to support both home users and roamers.

This document intends to....

In this document, an overview of IMS is provided and the impact on emergency communications is explained. It explains the concept of an ESINet and the benefits and needs for an ESINet and ESINet peering.

This document contains....

The document provides details and examples for how to handle emergency communications over IMS (including when there are legacy circuit-switched networks elements) for both home network subscribers and roaming subscribers. The need for, and benefits of, Emergency Services IP Network (ESInet) peering is apparent in the examples given.

Terms and Definitions

2G, 3G, 4G, 5G	2nd, 3rd, 4th and 5th generations of mobile network technology
3GPP	3rd Generation Partnership Project
AML	Advanced Mobile Location
BCF	Border Control Function
CS	Circuit-Switched
CSCF	Call Session Control Functions
C-CSCF	Control CSCF
E-CSCF	Emergency CSCF
EPC	Evolved Packet Core
EPS	Evolved Packet System
ESInet	Emergency Services IP Network
HSS	Home Subscriber Server
IBCF	International BCF
I-CSCF	Interrogating CSCF
IMS	IP Multimedia Subsystem
IP	Internet Protocol
LBO	Local Break Out
LRF	Location Retrieval Function
LTE	Long Term Evolution
MGW	Media Gateway
MME	Mobility Management Entity
NGCS	Next Generation Core Services
NNI	Network-Network Interface
P-CSCF	Proxy CSCF
PGW	Packet-data Network Gateway
PSAP	Public Safety Answering Point
PSTN	Public Switched Telephone Network
QCI	QoS Class Identifier
QoS	Quality of Service
RAN	Radio Access Network
S8HR	S8 Home Routing
SDP	Session Description Protocol
SIM	Subscriber Identity Module
SIP	Session Initiation Protocol
UE	User Equipment
URN	Uniform Resource Name
ViLTE	Video over LTE
VoLTE	Voice over LTE

Introduction

By 2025, it is projected[1] that 86% of the European population will be using 4G or 5G mobile communications. 4G technology, and all subsequent generations of mobile network technology, are based on packet-switched infrastructure (if one disregards fallback to circuit-switched communications based on 2G or 3G technology). With this change, telephony services are provided on IP Multimedia Subsystem (IMS).

In this document, an overview of IMS is provided and the impact on emergency communications is explained. An interesting technical detail to get started is the fact that traditional telephone numbers only play a minor role in packet-switched infrastructure. For example, in the case of an emergency communication, the end-user would still dial the emergency number, but the device would then use a so-called "service URN[2]", which is best described as a namespace string to uniquely identify an emergency service like ambulance, fire, police, or mountain rescue.

The document provides details and examples for how to handle emergency communications over IMS (including when there are legacy circuit-switched networks elements) for both home network subscribers and roaming subscribers. The need for, and benefits of, Emergency Services IP Network (ESInet) peering is apparent in the examples given.

[1] GSMA – The Mobile Economy -Europe
[2] https://datatracker.ietf.org/doc/html/rfc5031

IP Media Subsystem

For a better understanding of IMS and packet-switched emergency communications, a better understanding is needed about how IMS and emergency communications work. The basic function of IMS is to control and manage service and application sessions in a converged multimedia network, whether fixed or mobile. It acts as a routing or session control instance that matches user and/or service profiles and routes communications sessions to the appropriate destination. This function also applies for emergency communications.

The Role of IMS in Emergency Communications

Electronic communications on 4G and 5G networks rely exclusively on IP-based communications and need appropriate services to enable emergency communications. IMS provides the necessary services.

IMS was first introduced in 3GPP Release 5 as a standardised, access-independent, IP-based architecture. The IMS architecture enables the establishment of peer-to-peer IP communication with different types of clients and proper service quality. In addition to session management, the IMS architecture also supports functionalities necessary for service delivery like registration, security, billing, bearer control, and roaming. As the name suggests, a basic requirement is that a device must have an IP connection to access an IMS. 3GPP has decided to use a layered architectural design. This means that transport and bearer services are separated from the IMS signalling network and session management services as shown in Figure 1.

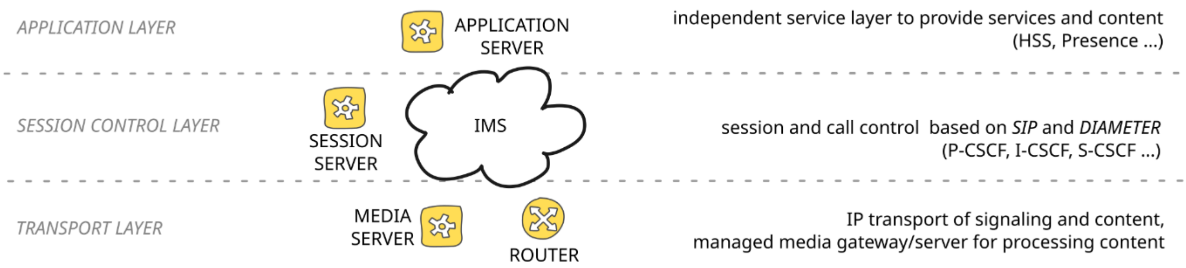

Figure 1*: IMS elements and layers*

The most important elements of an IMS are the Call Session Control Functions (CSCFs):

- Proxy-CSCF (P-CSCF)
- Interrogating-CSCF (I-CSCF)
- Serving-CSCF (S-CSCF)

All CSCFs have in common that they play a role during registration and session setup and together form the Session Initiation Protocol (SIP) routing infrastructure of an IMS. P-CSCF and S-CSCF may release sessions on behalf of the user (e.g., when S-CSCF detects a hung session or P-CSCF receives a media loss notification) and can check the content of the Session Description Protocol (SDP) payload. For instance, if the proposed SDP does not comply with the operator's policy, the CSCF rejects the request and sends a SIP error message to the UE.

Using a normal call to a fixed network as an example to understand which IMS elements are involved in the process. To get an IP connection to the IMS subnet (as explained later in this document), it is necessary to complete an Evolved Packet System (EPS) attachment procedure and to be registered with the IMS. Authorisation to use IMS services is determined by the subscriber profile stored in the Home Subscriber Server (HSS). The next step, as shown in Figure 2, is to dial the appropriate telephone number and start an IMS-based call-setup procedure. In very simplified terms, the call-setup messages are forwarded via P-CSCF and S-CSCF to a signalling and media gateway (MGW) to set up the call via CS infrastructure to the fixed network subscriber.

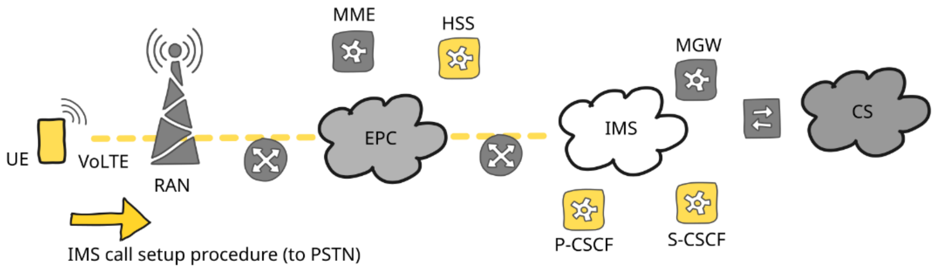

Figure 2: IMS call setup (CS)

After the UE has exchanged SIP signalling messages with the IMS, the EPS will create a dedicated bearer with QCI-1 for a voice call. QCI refers to QoS Class Identifier and determines traffic priority, maximum delay, and maximum packet loss that nodes shall provide when forwarding traffic belonging to this bearer. This mechanism is worth highlighting as the same principles also ensure higher priority for emergency communications.

The term "bearer", often regarded as an antiquated term from the time of ISDN, is understood to mean a channel that carries call content. When a call was set up, the bearer capability was negotiated and used to determine what type of traffic would be sent. Today, in mobile communications, this refers to a packet-switched (IP-based) data connection. Before accessing a website, for example, an EPS attachment procedure is required to establish (or negotiate) the data connection for Internet traffic.

This attachment procedure is also used by the UE to register with the network and establish a bearer between the UE and the PGW (Packet-data Network Gateway). To do so, the UE sends a request to the Mobility Management Entity (MME), which performs authentication and security of the UE and informs the HSS about the new network attachment region. The MME then uses the subscriber information received from the HSS to create the requested bearer, in most cases to simply connect to the public Internet, as illustrated in Figure 3a. Steps 1 to 6 in the sequence diagram (Figure 3b) show a simplified message flow and the functional elements involved.

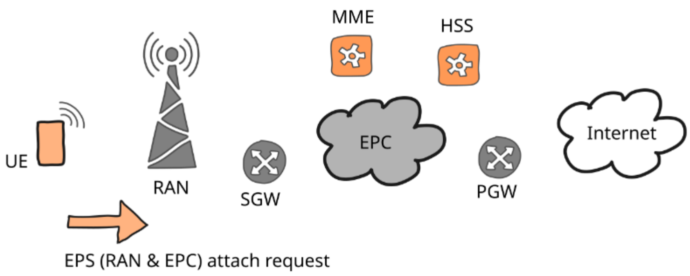

Figure 3a: EPS attach request

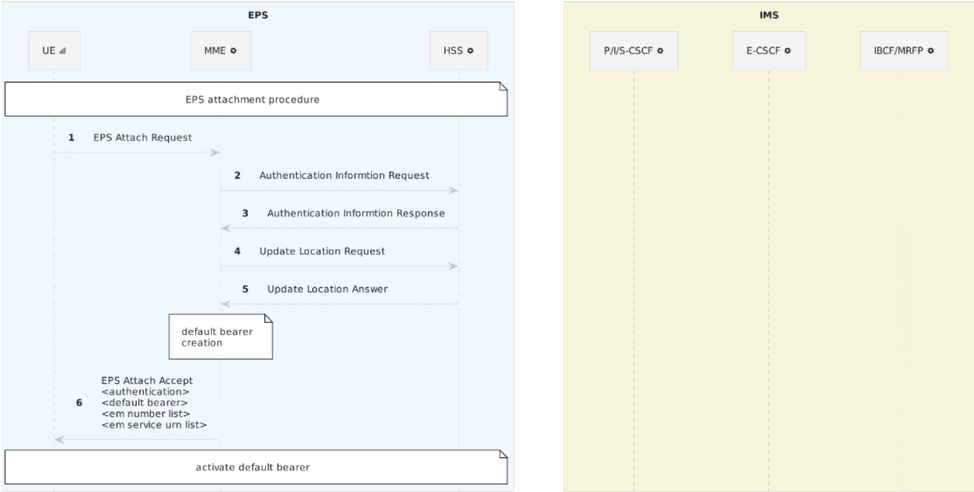

Figure 3b: Sequence Diagram (Steps 1 to 6)

An important point to be aware of is that the serving network's MME may, depending on an MNO's configuration, download a list of local emergency numbers to the UE to enable it to recognise an emergency session. This information is transmitted in the EPS Attach Accept response received by the UE from the MME, as shown in Figure 4.

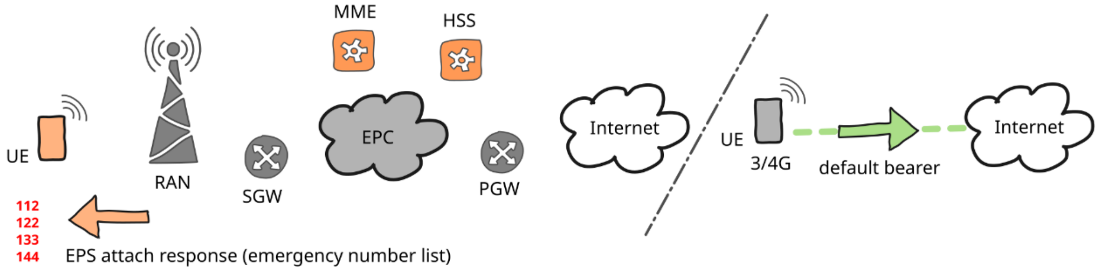

Figure 4: EPS attach response

The example given in Figure 4 may be the list provided by an Austrian mobile network operator MME. Just to note that this is important for roaming scenarios where the visited MME downloads the local or extended emergency number list to the visited UE. There are several ways to store emergency numbers in a UE be it via firmware, Subscriber Identity Module (SIM) or by downloading during the described attachment procedure. In principle, it is up to the UE or provider how numbers are displayed to the user for emergency calls.

The essential part is that a UE recognises whether an emergency number has been dialled as this enables the necessary steps to be taken to be connected to the appropriate emergency communications centre. In general, emergency numbers are associated with countries defined by the Mobile Country Code (MCC) and the emergency number list is discarded by the UE when entering a new country. Just note that if a roaming subscriber's UE is not aware of the emergency number, the call is handled through the normal session setup.

Roaming

The previous example related to a home subscriber in the home network. What happens when a subscriber's phone disconnects from its home carrier's network and attaches on another available network? With roaming, there are two main variants of implementation in terms of data connectivity: home-based routing (S8HR) and local breakout (LBO).

In home-based routing, IMS calls are served by the visited network provider as a data roaming session, like the way that Internet traffic is handled by just utilising the visited network's EPS. The 3GPP interface between the serving and home network is called S8, which is where "S8HR" comes from. Within the S8HR scenario, the home network contains the IMS core network, while the visited network does not.

With traffic routed back to the home network, emergency communications are not routed locally. For example, if an emergency number is dialled by a roamer in a visited network, the dialled numbers are passed to the home network, and the home network is responsible for trying to complete the call. Depending on the subscriber's location (country), those numbers may or may not properly translate. One interim solution is that operators fall back to CS for emergency calls.

With local breakout, the serving network, and the home network both have an IMS involved. Within the local breakout roaming method, call control and bearer components are served by the visited network. In addition, both the serving network and the home network have an IMS Roaming network-to-network interface (NNI) in place. This means that both the visited network and home networks can communicate with each other via IMS.

LBO better supports emergency communications as the visited network IMS has visibility of the emergency call setup procedure. Regardless of the two scenarios, it is important to distinguish whether a UE recognises a call as an emergency call or not. In case the UE can recognise an emergency call (in the 3GPP standards, this is called "detectable EC"), it initiates an emergency call setup procedure to support a high priority in case of network congestion, as illustrated in Figure 5.

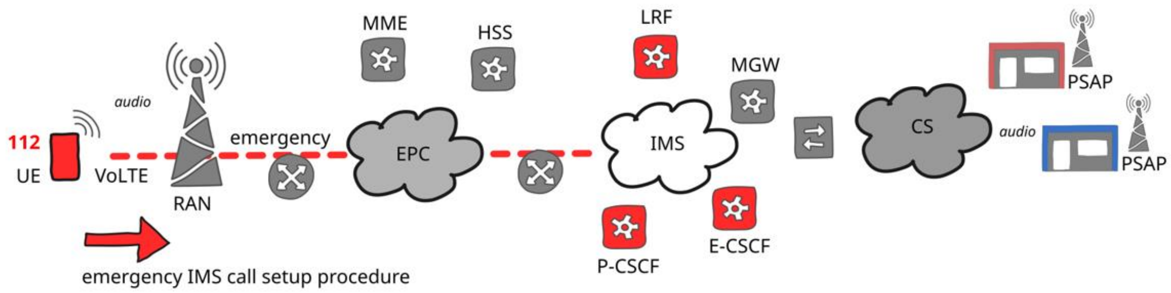

Figure 5: IMS call setup (CS)

To do so, the UE may or may not be normally registered with the IMS. In case it is already registered and located in the home network, the UE may perform an IMS emergency session establishment without prior emergency registration. Otherwise, the UE performs an IMS emergency registration before the session establishment.

IMS Emergency Communication

To support emergency communication, the IMS has another session control element known as Emergency-Call Session Control Function (E-CSCF). The main tasks are:

- to receive emergency session establishment requests from a P-CSCF
- to optionally request the Location Retrieval Function (LRF) to retrieve location information or to validate the location information included by the UE
- to determine proper routing information (next hop) and route emergency session requests to an appropriate destination including anonymous session requests
- subject to national requirements, to send the contents of P-Asserted-ID, P-Access-Network-Info, or UE identification to the LRF

The LRF manages the handle and retrieval of location information for the UE. Note that in the above example, a public safety answering point (PSAP) is only connected via CS. This reduces emergency communications to a plain voice call and multimedia services like video or text cannot be used. In addition, precise or better location information of the caller may only be achieved using Advanced Mobile Location (AML) support. If one wants to improve on this approach, there must be a packet-switching infrastructure up to the PSAP. Ideally, there are corresponding services in this infrastructure (referred to in the standard as next-generation core services (NGCS).

The idea of these core services is very similar to that of IMS. It is about choosing the most appropriate PSAP in an IP-based (packet-switched) infrastructure, independent of the originating network. This infrastructure- also called Emergency Service IP Network (ESInet)- supports, besides location-based routing, multimedia emergency communication like audio, video, and real-time text. Further details can be found in ETSI TS 103 479[3].

Looking again at the example from earlier, it is now possible to have end-to-end communications sessions. With valid certificates, a secure interconnection (peering) between IBCF and BCF is possible, as shown in Figure 6a. Steps 1 to 8 in the sequence diagram (Figure 6b) and further steps 8 to 13 (Figure 6c) show a simplified message flow and the functional elements involved.

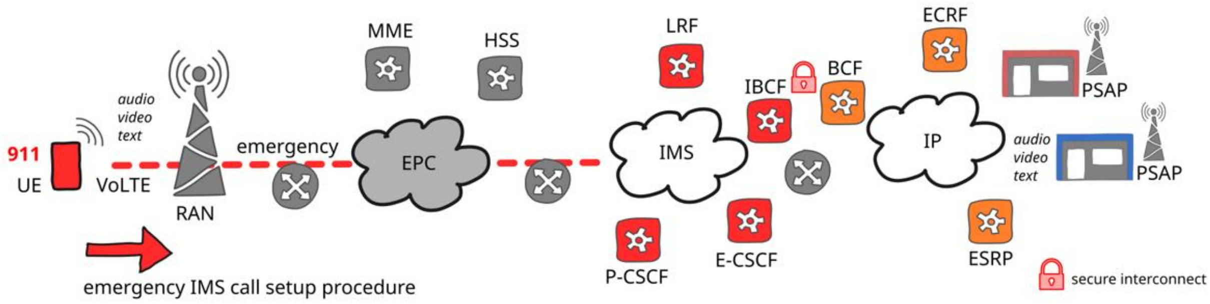

Figure 6a: Emergency IMS call setup

[3] ETSI TS 103 479 V1.2.1, Emergency Communications (EMTEL); Core elements for network independent access to emergency services, March 2023.

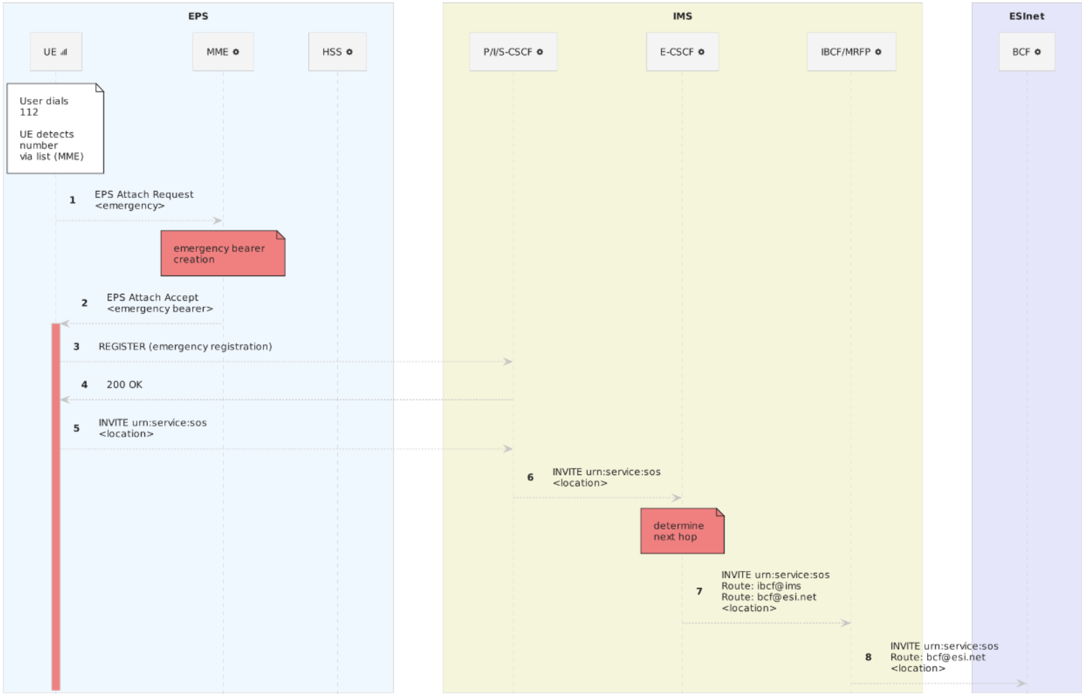

Figure 6b: Sequence Diagram (Steps 1 to 8)

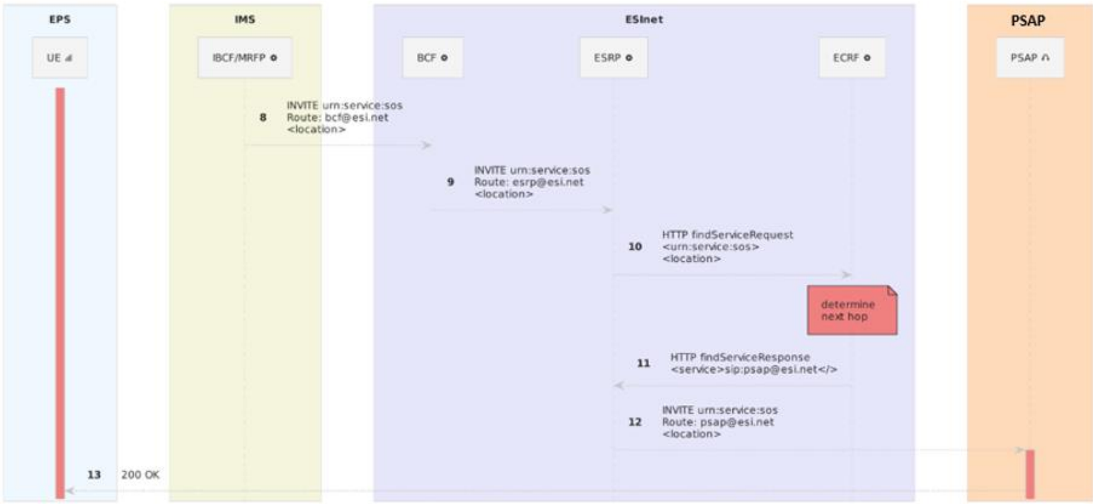

Figure 6c: Sequence Diagram (continuing steps 8 to 13)

If a UE does not detect a dialled emergency number as an emergency call, a normal IMS call setup (for example a 911 call) will be established without the necessary priority. There is a so-called last resort to tell the UE to perform an IMS emergency call setup or a CS fallback for emergency calls. This also works in a home-routed scenario provided that the IMS (i.e. the P-CSCF) recognises the dialled number or service URN as an emergency call, as illustrated in Figure 7.

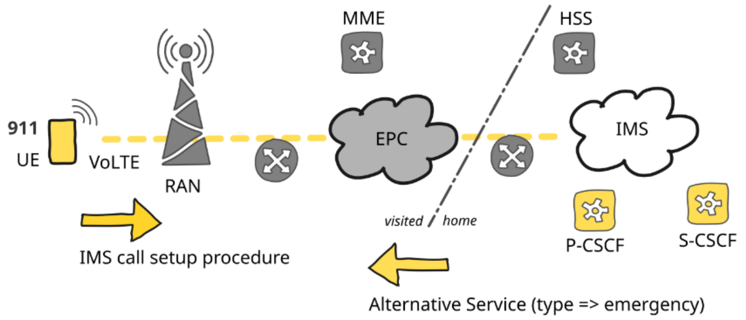

Figure 7: Alternative service

With this mechanism, the UE is informed about an "Alternative Service" with the type of emergency. With this, a UE can then perform an appropriate emergency call setup (e.g., to 112) as described earlier and shown in Figure 8

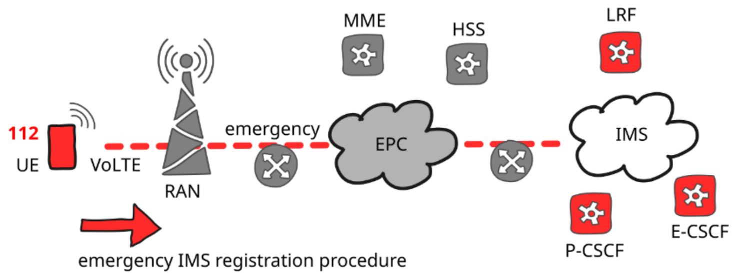

Figure 8: Emergency IMS registration

Conclusion

In conclusion, it can be said that an IMS for VoLTE and ViLTE (Voice and Video over LTE) provides sufficient standardised mechanisms to forward emergency communications to an *ESInet*, as listed below:

- IMS in combination with the EPC of a mobile network operator supports emergency communications to 112 and the configuration of local or regional dial strings to address specific local emergency numbers and services. This allows mobile devices to detect a user's individual need for emergency communications.
- GSMA has defined profiles[4] for real-time text according to RFC 4103[5], which enables global accessibility to emergency communications if the profiles are enabled in the IMS.
- In addition, GSMA recommends[6] the use of LBO for emergency communications. If the mobile device detects an emergency communication, it ensures that there is always communication with the local PSAP or infrastructure.
- It is also important to note that by 2025, the subscriber base is expected to grow to 480m subscribers in Europe[7] (equivalent to 86% of the European population). This requires a technical solution for emergency communications that is compatible with IMS.
- Finally, it should also be added that a packet-switched infrastructure up to and including the PSAP combined with next-generation core services is also applicable for other originating networks as shown in Figure 9

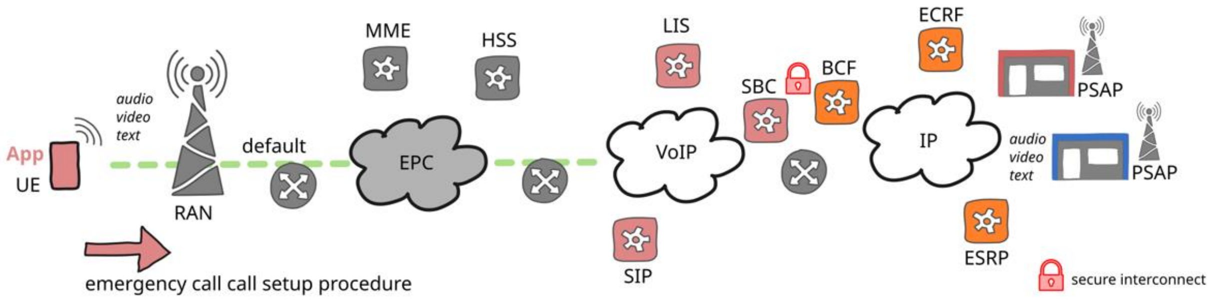

Figure 9: Emergency communication example

[4] GSMA Document, IMS Profile for Voice, Video and Messaging over 5GS-Version 2.0, 07 August 2020
[5] https://datatracker.ietf.org/doc/rfc4103/
[6] GSMA Document, NG.119 – Emergency Communications-Version 2.1, 29 May 2023.
[7] GSMA – The Mobile Economy -Europe 2022