Published by :
http://www.ijert.org

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 6 Issue 02, February-2017

Emergency Call Routing Schemes

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***Abstract*— Due to the unpredictable occurrences of accidents in the community, countries the world over are implementing schemes to ensure that such emergency situations are well relayed and attended to by the appropriate emergency organization. Thus, emergency call routing schemes have become popular today. In this paper, the different schemes implemented in the USA, UK, and Australia are discussed and general recommendations are made for implementing an emergency scheme in a developing nation such as Ghana.**

***Keywords*— PSAP, call routing, VoIP**

I. INTRODUCTION

Every year several millions of people dial an emergency number to access emergency services. An emergency can be presented in many forms; from every day incidents like traffic accidents or assault, to major incidents like airplane crashes, forest fires, earthquakes or large-scale terrorist attacks [1]. Thus the allowance of victims to communicate issues to the appropriate authority has become important. Emergency call routing (ECR) is therefore defined mainly to help address emergency situation in societies within the shortest time possible.

Over the years, different countries have implemented various schemes to tackle the issue of emergency call routing, each having their own code. However, not much review has been done on the subject matter, and neither is any such scheme implemented in most developing countries. Therefore, the focus of this paper is to present an overview of emergency call routing schemes and review some schemes implemented in countries such as the USA, UK, and Australia, and make recommendations of a potential ECR scheme for a developing country such as Ghana.

II. A GENERAL OVERVIEW OF EMERGENCY CALL ROUTING

Emergency call services are not a subscribed service of the caller, but are provided by the local area, from which the caller accesses the network. They may require priority treatment such as providing a high quality bearer path regardless of subscription [2].

Emergency calls should have priority over all other calls and the priority should be ensured across public networks. If the network is not operating under abnormal conditions as a result of a disaster, the speech quality of emergency calls should not be worse than for basic telephone service handled in these conditions. Otherwise, if the network is operating under abnormal conditions and a trade-off exists between speech quality and connectivity, connectivity should have priority over speech quality [1]. Because of the high priority attached to emergency calls, the 2002/22/EC directive made some provisions as to the access by individuals of emergency call services. These include [1]:

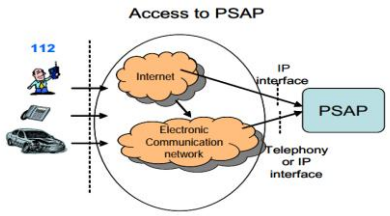

Fig.1. Access to PSAP via Telephony or IP interface

1. Ability of network resources to fulfill user's needs. This includes the ability of the user to access free-of-charge emergency call services from anywhere and with any device.
2. Ability of the public network access point to enable emergency calls in each situation, even when normal calls have been barred.
3. Recognition and treatment of emergency calls by the originating network. For each emergency call the originating network should generate emergency call-related information (e.g., location of the caller and calling line identification) and deliver this information to the public safety answering point (PSAP) or to the corresponding emergency control centre.
4. Delivering call-related information concerning user location.
5. Delivering call-related information concerning user identification.
6. Handling of emergency calls between networks. Originating networks should transmit their network identification to the emergency control centre.
7. Providing termination of emergency calls to the PSAP. The network should deliver the emergency calls together with any related data, without delay and modification to the PSAP which is directly connected to this network. If delivering an emergency call to the appropriate PSAP is not possible, it must be forwarded to the alternative PSAP.

Emergency calls were traditionally handled through the circuit switched network [3]. In Plain Old Telephone Service (POTS), emergency calls were detected and routed to the closest PSAP through a Public Switched Telephone Network (PSTN) where a phone number-phonebook method was used to match the location of the caller to the number. In mobile telephony, use was made of the access or trunk network element to find location information, which depended on the location of the handset, which in some cases was not in the 'phonebook'. Other types of services, such as Satellite Telephony, Data Calls, short message service (SMS), multimedia messaging service (MMS), and voice over IP (VoIP) are available for emergency call routing. Each service

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International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 6 Issue 02, February-2017

type may have its own interface to the PSAP. For instance, POTS used the PSTN interface, as mentioned above.

Irrespective of the type of service that hosts the emergency service or the type of interface that links the caller to the PSAP, an emergency call routing service must perform three basic functions [3]:

1. Routing to the appropriate PSAP (as defined by the relevant authority).
2. Identification of the caller (network identity through e.g. network time protocol (NTP) and/or universal/subscriber identity module (U/SIM).
3. Location of the caller.

Since IP allows for transfer of more information related to the call and the caller, it could be beneficial to allow for direct IP-interconnect to PSAPs, instead of using PSTNs. It is also foreseeable that the days of the circuit switched networks are coming to an end. That means that interface standard requirements for IP-interconnections of PSAPs must be quickly developed and clearly defined in order to standardize its application in different regions and countries. Many international groups such as Internet Engineering Task Force (IETF), 3rd Generation Partnership Project (3GPP), and European Telecommunications Standards (ETSI) are therefore working on it. Types of IP-based interfaces available include [3]:

1. IP-based telephony: In this case, the signaling information for call handling and the emergency related information will be delivered from VoIP session provider.
2. Internet telephony: In this case, the signaling information for call handling and the emergency related information will be delivered from user equipment

The above types of IP-base interfaces may make use of radio interfaces such as high rate packet data (HRPD), cdma 2000-1X, and wireless local area network (WLAN) [2].

A. The PSAP's Architecture and Organization of the Emergency Control Centres

Basic functional PSAP architecture is illustrated in Fig. 2. Depending on PSAP and emergency control centre physical locations this logical architecture can be mapped into two physical solutions shown in Figs. 3 and 4.

In the first case, illustrated in Fig. 2, the PSAP and emergency control centre functionalities are integrated into the same physical entity. In the second solution, shown in Fig. 3, the PSAP sits at the edge of the public network and its functionality is distributed and separated from functionality of the emergency control centre. In this case the network between PSAP and emergency control centre is a dedicated priority network, built using leased lines or secure virtual private network (VPN).

Three types of organizational setup of PSAP, emergency control centers (ECC) and emergency response operations (ERO) recommended by expert group on emergency Access (AGEA),which is the subgroup under the communication committee (COCOM) as well as the technical group chaired by European commission (EC), are presented by Fig. 5.

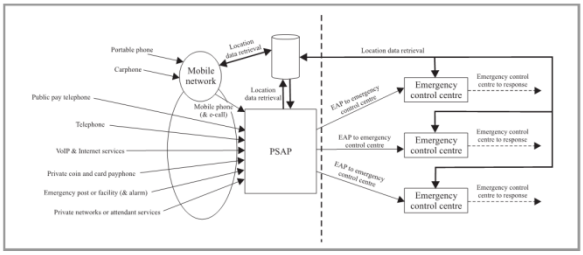

Figure 2. Basic functional architecture

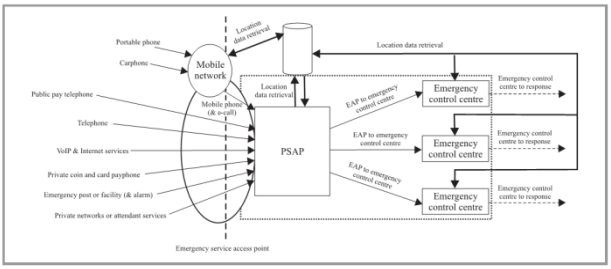

Figure 3. Integrated PSAP and Emergency control center

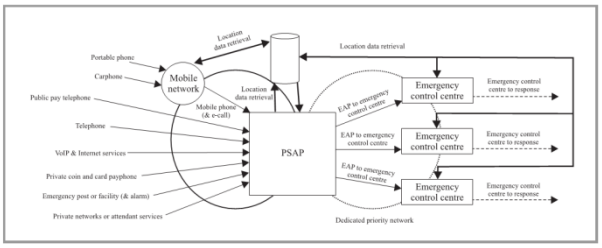

Figure 4. PSAP on edge of public network

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International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 6 Issue 02, February-2017

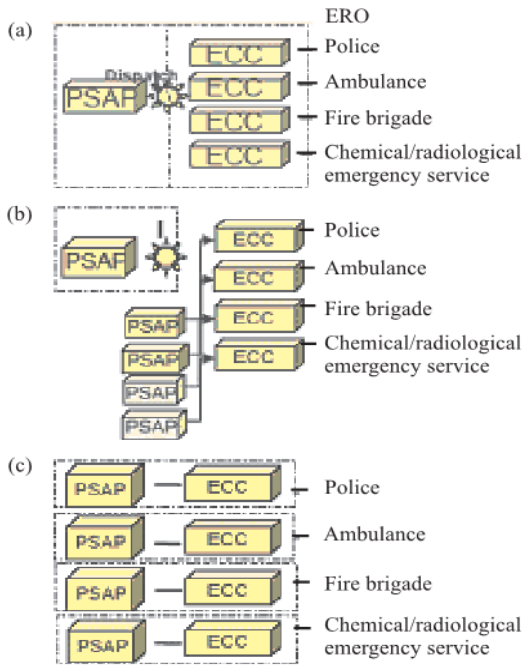

Figure 5. Basic types of organizational setup [3]: (a) single level 1 PSAP dealing with all emergencies; (b) single level 1 PSAP dealing with all emergencies + directly reachable ERO's having their own answering points; (c) separate PSAPs dealing with emergencies

III. SOME EMERGENCY CALL ROUTING SCHEMES

A. The 911 and E911 service of the USA

Emergency call routing is commonly referred to as 911 in the United States because of the use of the 911 pattern to route emergency calls to the local emergency services call center [4]. The first 911 system was installed in Haleyville, Alabama, in February 1968, as a way to quickly connect a subscriber to the local police station. The system was rapidly adapted and improved by other telephone companies, evolving into the E911 system, which provides both caller location and identification [6]. The major distinguishing feature of Enhanced 911 (E911) is the ability to selectively route a 911 call to a designated PSAP based upon the caller's location [7].

911 calls are serviced through a PSTN, and its service architecture usually satisfies the following requirements [8]:

1. A distressed caller should be able to dial the emergency services from a fixed line, a mobile phone, a public phone, or any device capable of making the voice call.

2. An emergency services call handler must be available to respond to the emergency request and dispatch the needed services such as police, fire, and medical.

3. In order to provide help, the call handler should be able to identify the location of the distressed caller as precisely as possible.

4. An emergency services network is needed to route the call to the nearest emergency services call handler with jurisdiction for the location of the caller.

Assuming that the first requirement is satisfied, a 911 call must be sent to the right emergency service center. The emergency services call center is commonly referred to as the PSAP [4] and is the party responsible for answering the 911 call and arranging the appropriate emergency response team (ERT). First responders ERT include members of the fire department, police department, and/or ambulance depending on the emergency situation [4].The physical location of the phone making the 911 call is the primary factor in determining the appropriate PSAP for answering that call. Generally, each building is serviced by one local PSAP [8]. Different PSAPs may be serviced by different 911 network service providers.

A 911 call, when placed, is routed across dedicated, regionally significant networks to a special facility called a Class 4 telephone switch or Tandem Office. The Tandem Office uses a technology referred to as selective routing, controlled by local exchange carriers (LEC) [8], to query a selective routing database (SRDB) and master street address guide (MSAG) using the originating telephone number as a search key to match the origination of the call to the network location or emergency service number (ESN) of the appropriate PSAP [6]. The call is then routed to the appropriate PSAP.

For every 911 call arriving at the appropriate PSAP, PSAP software performs automatic location identification (ALI) by looking up the calling party's phone number (ANI) against an ALI database which has access to a MSAG. The MSAG includes the address of the caller who placed the call to the 911 center [4], and by its lookup, appropriate ERT is dispatched to the caller's location [4] by the telecommunicator, a specially trained official who answers the 911 call [6]. The ALI database is maintained on behalf of the local emergency services administration by a contracted third party, generally the incumbent LEC [8]. If the phone number is not passed or the phone number is not in the ALI database, this is known as ALI Failure; the call is then passed to the trunk group's default ESN, which is a PSAP designated for this function. The tele-communicator must then ask the incoming caller for their location and redirect them to the correct PSAP [6].

There may be multiple PSAPs within the same exchange or one PSAP may cover multiple exchanges. The territories (Emergency Service Zone) covered by a single PSAP is based on the dispatch and response arrangements for the fire, police, and medical services for a particular area [6].

As already mentioned, there are several 911 network service providers that service the different PSAPs, and their ALI databases are managed by LECs. Typical situations include [8]:

1. For a given street address, the 911 network service provider is the incumbent LEC. For a location served by Phone Company X, the corresponding PSAP is also served by Phone Company X.

2. All 911 calls are routed directly to an off-net location, or all 911 calls are routed directly to an on-net location.

However, some exceptional cases may arise. These include [8]:

1. The LEC through which the multi-line telephone system (MLTS) interfaces to the PSTN is *not* the same LEC that serves as 911 network service provider to the PSAP. (For example, the communications system is served by Phone Company X, but the PSAP is connected to Phone Company Y.)This situation might require either a special arrangement between the LECs or special, dedicated trunks between the phone system and the PSAP's 911 network service provider.

2. Some LECs may not accept 911 calls on their networks. If this is the case, the only two options are to change LECs or to establish trunks (dedicated to 911 call

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International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 6 Issue 02, February-2017

routing) connected to a LEC that can route 911 calls to the appropriate PSAPs.

3. Some (or all) of the 911 calls have to be routed to an on-net location such as campus security or building security. This situation can easily be accommodated during the design and implementation phases, but only if the destination of 911 calls for each phone has been properly planned and documented.

In additiontoproviding voice communications, the interfaces usedtopresent911callstothenetworkmustalsoprovideidentificati on data about the ANI. Two types of interfaces are available [8]:

1. Dynamic ANI: This type of interface usually connects a communications system to a PSTN Class 5 switch. The ANI is used at call setup time to identify the E.164 (non-emergency) number of the calling party.

2. Static ANI: Static ANI provides a line (rather than a trunk) connection to the PSTN and the ANI of the line is associated with all 911 calls made on that line, regardless to the CPN of the calling phone. A plain old telephone service (POTS) line is used for this purpose.

B. Australia's Triple Zero (000)

Triple Zero (000) is the primary national emergency number in Australia. The number Triple Zero (000) was chosen for several reasons: technically, it suited the dialing system for the most remote automatic exchanges, particularly outback Queensland. These communities used the digit 0 to select an automatic trunk line to a centre. In the most remote communities, two 0s had to be used to reach a main center; thus dialing 0+0, plus another 0 would call (at least) an operator. Zero is closest to the finger stall on Australian rotary dial phones, so it was easy to dial in darkness. [9]. There are also two secondary emergency service numbers (ESN); 106, which is an ESN for the delivery of emergency calls to the national relay service provider (NRSP); and 112, which is an international emergency service number available on a range of mobile devices [10].

The key component of the national emergency call system is the 'around-the-clock' emergency call service (ECS) operated by emergency call person (ECP). Any caller has free-of-charge access to the ECS from a standard telephone service (for example, fixed-line, mobile, satellite, teletypewriter) to request that an operator transfer the call to the desired state/territory emergency service organization (ESO) (police, fire or ambulance). Calls to the ECS numbers are routed with priority in each carrier's network through a system of dedicated lines. Calls to Triple Zero and 112 about state or territory emergency services (for example, calls reporting natural disasters such as storm or flood damage to the State Emergency Services) are switched to a recorded voice announcement informing the caller how to contact the state or territory emergency service directly. [11]. A diagram showing how the 000 and the 112 ECS works is shown in Fig.6.

The ECS number 106 is provided for callers who rely on the use of a text telephone such as a teletypewriter (TTY) because they are deaf or speech/hearing-impaired. For calls to the 106 text ECS, the relay operator stays connected to the call to provide the relay between the emergency caller using text telephony and the ESO operator using voice telephony [11].

When a caller makes an Emergency Call for assistance, the call is first answered by the ECP. The ECP is currently Telstra for 000/112 and Australian Communication Exchange for text (TTY) emergency 106. For calls from a Fixed Local service, the ECP operator receives on their screen the calling line identification (CLI) and, sourced from the integrated public number database (IPND), the service address, which may be the location or address of the service from which the call is being made. For calls from an ETS where the address may not reflect the location of the caller (i.e. mobile or VoIP services) the ECP operator receives on their screen the CLI associated with the call and standardized location information. The service or customer address information is then passed to the ESO (police, fire or ambulance) by a data link along with the call. For services other than a Fixed Local service the ECP operator and ESOs are dependent upon the caller providing details of their location for accurate connection of the call. For these calls, the operator will ask two questions of the caller [10]:

1. Do you require police, fire or ambulance? And

2. In which state and town is the emergency?

Verification of State is necessary as there are many instances of multiple localities with the same name in different States and Territories within Australia. Due to this, the ECP must verify the State to ensure correct connection to the required ESO. CLI and address details are very important to the ESO call-taker when managing the call. The details received are displayed on the operating screen in front of the ESO operator taking the call. In many cases the location details of the caller are superimposed on the ESO location mapping and tasking screens based on the data feed derived from the IPND [10]. Upon receipt, the right emergency service organization is dispatched.

C. 112/999/18000 of the United Kingdom

In the UK, there are three emergency numbers; 112 which is used in any part of the EU, 999, and 18000 which is used for International Telecommunication Union (ITU) text over voice applications [12]. In carrying out their emergency call routing scheme, every communications provider (CP) must ensure that any end user can access emergency authorities (EAs) by using the emergency numbers 112 and 99 at no charge and, in the case of a pay telephone, without having to use coins or cards. In the case of mobile networks, enabling 999 or 112 emergency calls to be made from mobile telephones which do not have radio coverage from their normal network provider is expected to allow the public to maximize chances of quickly making an emergency call [13].

The CP must also make caller location information (CIL) – a piece of information that gives the geographical location of the terminal equipment being used - available to the EAs, to the extent technically feasible, for all calls to the emergency numbers 112 and 999. The CPs deal with the requirement to provide a public emergency service by contracting with a call handling agent (CHA). In the UK, British Telecommunication (BT) and Cable & Wireless are the two CHAs [13].

The handling of an emergency call by a CHA involves the five main phases:

1. Connection of the caller over the CP and CHA networks to the CHA's emergency operator (EO) via the 999 or 112 number.

2. Selection by the EO of the required EA control room (EACR). Before connecting a call to the relevant EA, the EO obtains from the caller which EA is required, and the telephone number of the caller. In the case where more than one EA is required, they will be connected to all EAs requested in the order that they are requested. When an EO answers an emergency call, the full national calling number,

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International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 6 Issue 02, February-2017

and for mobile calls, the zone code or Cell ID will automatically be displayed on the operator's console. Based on matching the EACR areas to the calling number's postal code or zone code, EACR routings are automatically displayed. The EO then selects the appropriate one.

3. Onward connection of the caller to the EACR over the CP/CHA networks.

4. Listening by the EO to ensure that connection has been established with the appropriate EACR and the ability to provide further assistance to the caller or EA when required.

5. Provision of location information to EA.

IV. COMPARISON OF SCHEMES

Having reviewed the different schemes available in the USA, Australia and the UK, some similarities have been observed. Three key similarities include:

1. Emergency calls can be made with both mobile and fixed telephones, and do not require SIM cards to be made.

2. There is a common emergency number for users, which when dialed, goes to an intermediary agent before the right emergency organization is dispatched.

3. The use of an address system, automatic to some level, to extract location of caller. This extraction takes place at the intermediary agency.

However, there are some slight differences in the implementation of the various schemes, which give each of them their various characteristics. Some of these differences include:

1. In the USA, there are two intermediaries between the caller and the emergency response team: the LEC to route the call to the appropriate PSAP, and the PSAP to look up the location of the caller and dispatch the appropriate emergency team. On the other hand, the UK and Australia have one intermediary; the EA for the UK and the ECP for Australia. The use of two intermediaries may present an advantage over the use of one intermediary. LEC that connect in-coming calls to the appropriate PSAP potentially save time.

2. The 000 scheme of Australia is also adapted to address national issues such as floods and bush fires. This is observed in the provision made for regional or national emergencies, to direct callers on mitigating issues before an emergency team is dispatched. This, if present in the UK and USA, is not as developed as in that of Australia.

3. The UK and Australia both have multiple numbers for emergency services, which is not the case in the USA. Whereas the UK and Australia both have three, the USA implements only one common emergency number. The main advantage of only one emergency number usage is that it erases probable confusion and allows all resources to be channeled in the development of a single emergency service. The use of three emergency numbers on the other hand leads to easier access to emergency services, since there are options in case of network failure for one of the emergency numbers.

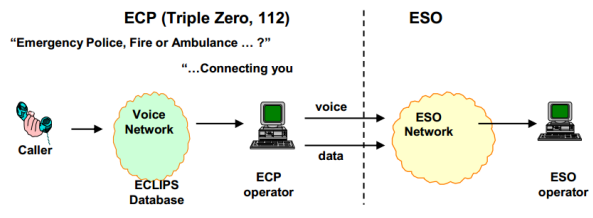

Figure 6. Basic functional architecture of the ECS

V. CONCLUSION AND RECOMMENDATIONS FORAN EMERGENCY SCHEME IN GHANA

Having looked at the various schemes implemented in the USA, Australia and the UK, one major and striking observation can be made: First, without a proper street and town address and/or location system, implementing an effective emergency scheme will be difficult. As Ghana faces the challenge of proper town and city planning and addressing, the first step will be to redesign and address our streets, towns and cities more appropriately. This will allow an up-to-date and comprehensive address guide for use in the emergency scheme.

Secondly, each of the schemes reviewed above has a reliable network to route emergency calls. Ghana lacks reliability on some of its networks. Coupled with inadequate coverage of the country on its telecommunication networks, some town and areas are bound to have challenges accessing emergency services when necessary. Thus, it will be necessary that prior to the implementation of an effective emergency scheme, all telecommunication networks operating in the country be made to have domestic roaming in the country.

Again, fixed telephone services were available in all of the countries whose emergency schemes were reviewed. Very little of such service is currently available in Ghana. This is a problem, considering the fact that a sizeable percentage of the population (usually in the rural areas) does not use cell phones. Even though fixed telephones may not be very appealing an option to service providers, temporary call centers could be set up in rural areas to ensure that the part of the population not exposed to this service are covered.

In conclusion, having reviewed the emergency scheme system in the USA, UK and Australia, it is recommended that an effective emergency scheme in Ghana should consist of the following; one intermediary between the caller and the emergency service team, since the population of Ghana is not large and therefore, light traffic is expected. The scheme should make use of one single emergency number in order to prevent confusion. It is also recommended that the scheme allows for several languages, and allows the caller to be directed on what to do while waiting for the emergency team.

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