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A Comprehensive Survey of Emergency Communication Network and Management

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Abstract
The performance of wireless communication network is important in emergency rescue operations while ensuring optimum usage of limited wireless resources. Due to the disruption of normal wireless communication in a post-disaster scenario, the sustenance of an emergency communication network plays a significant role in relief operations. Under such a scenario, it becomes crucial to monitor the performance and reliability of the protocol in a time-bound manner. Some of the prominent challenges faced by the communication network during this period are related to energy efficiency, resources allocation, reliable connectivity, QoS, network throughput, and interoperability. A comprehensive performance appraisal of the emergency network considering the above-mentioned aspects is extremely important. This review provides a comprehensive survey of the widely used communication technologies applied for setting up an emergency communication network to mitigate the post disaster aftermath. The article also delivers an overview of the integration of new technologies with the existing standards for improving the performance of the disaster communication networks. Finally, we propose some promising solutions to overcome the limitations of existing emergency communication technologies to improve the overall network performance.

Keywords Disaster communication · Emergency communication network management · Public safety and rescue

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1 Introduction

Disaster is an inevitable circumstance that mankind has to go through in their mortal existence. Disaster in any form causes serious disruption in coordinated response and recovery efforts due to organizational, technical, procedural, random, or deliberate attack could result in the risk of massive loss of life. It also may cause severe economic emergencies for a nation and degrade environmental conditions for living. The recent pandemic situations during the past decade suggest that urgent action is essential to ensure an optimal information sharing environment for a normal healthy life. In the absence of an efficient backbone network, the people will be left scrambled to establish communication. For optimal use of network utility, valuable network resources have to be managed efficiently and at the same time, user awareness regarding social applications need to be developed and make people aware of the use of the internet.

Visualizing the aspects of pre- and post-disaster communication scenarios, we analyze that the network congestion should be minimized as much as possible to provide a proper network utility and reach maximum coverage in disaster locations. In post disaster situations, the limited resource is to be optimally utilized to handle the sudden upsurge of congestion in the network. That strategy improvises the network congestion and assures network service for the disaster affected users and rescue teams. Many countries are still in their learning phase and lagging behind in developing such social network services or internet services for their citizens located at the remotest corner of the country. An efficient emergency communication on top of a disaster communication backbone architecture is one of the most essential components for any nation.

In recent years, the enthusiasm for research in improvement of disaster management systems is increased and the government also wants to implement the most advanced technology to reduce the losses due to disaster. However, there is no such development in architectural design is achieved till now. As most of the present disaster management systems rely on the existing network infrastructure, the risk factor is unchanged. In literature, we observed the uses of WLAN, Bluetooth (BT), Wi-Fi, and WiMAX in Ad-Hoc framework to model emergency communication architecture in infrastructure-independent networks.

For rescue in disaster user's portable device have to be equipped with emergency services. In [1], the authors have proposed an Internet of human network by using a protocol named ORACE-Net which can be implemented on any smart devices such that people could manage to rescue in after disaster phase. In [2], authors have discussed, how on the basis of actual seismic hazard information and geographic location new communication links are to be included in the existing network in order to minimize the total end-to-end disconnection probability. For rapid setup of emergency network, a movable and deployable resource unit (MDRU) is proposed in [3], which proved to be very useful in establishing rapid setup of an emergency network.

The next concern deals with the utilization of spectrum in a cognitive way to minimize the network overhead. It is observed that when a network control station (Base Station Controller (BSC) or Mobile Switching Center (MSC)) gets down, a large geographical area comes under black-out zone. In this situation, the spectrum sharing strategy will be beneficial for balancing the network congestion and improve network QoS. In general, every network operator gets some licensed spectrum from the spectrum governing authority. If protocol has been modeled for sharing some percent of the allocated spectrum in operator independent mode, then blackout user can be served in emergency operator independently.

This article first discusses the Public Safety (PS) network operated till date about their working principle and how their standard technology helps the rescue team by preventing and minimizing the loss of human lives and property by alerting the people. Simultaneously discussion has been made on the up-gradation of technologies and tools that proved helpful for the PS network to provide the desired communication requirement and support in disaster situations.

The main contributions of this paper are listed as follows:

In Sect. 2: We have discussed the communication system standard operated till date and observed the feasibility of all the standards in the Indian spectrum regulation. In Sect. 3, we have surveyed the potential future wireless communication technologies for disaster scenarios, and in Sect. 4, we discuss on all probable disaster management problem and their possible solution. Finally, with Sect. 5 we conclude the paper.

2 Safety System Standard and Related Spectrum Regulation

This section describes the technology behind the all-functional PS technological standards used for an emergency in wireless communications domain and the spectrum regulation strategy in India for deploying next-generation PS system.

Advancement in technology generates the motivation to utilize the limited spectrum [4]. In [5], authors present a spectrum occupancy measurement based on Indian perspective. The detailed spectrum utilization in different technology standard of the world is depicted in Table 1.

The functional operational area of disaster communication are as follows:

(a) Emergency crisis in urban area
(b) Natural disaster in a rural area
(c) Cross-border law enforcement
(d) Major Event
(e) Indoor Scenario

From [6, 7], we can identify the following are the key functions which a PS organization has to provide:

1. Law Enforcement
2. Emergency Medical and Health Services (EMHS)
3. Border security
4. Environment protection
5. Fire-fighting
6. Search and rescue
7. Emergency crisis

The different known technology standard and coverage areas, special services, operational scenarios are mentioned in detail in Table 2.

Unlike general wireless communications, the wireless network used in disaster relief has specific needs to be fulfilled.

- Provide Broadband Wireless communication

Table 1 Spectrum allocation for public safety system in United State, Europe and corresponding vacant or un-allocated spectrum in India

Frequency band	Spectrum allocation						Used PS standard
	United State		Europe		India		
	Tuning Range (MHz)	Available bandwidth (MHz)	Tuning Range (MHz)	Available bandwidth (MHz)	Tuning Range (MHz)	Available bandwidth (MHz)	
VHF (Low Band)	25–50	6.3				Marine and aeronautical navigation	DMR
VHF (High Band)	150–174	3.6				Aeronautical navigation	DMR (66–88)
220 MHz Band	220–222	0.1			170–230	Free (220–222)	Amateur Ham Radio (220–225)
UHF Band	450–470	3.7	380–385	5		Not allocated	TETRA (380–385), TEDS (410–430), TETRAPOL, DMR
			390–395	5			
700 MHz Band	764–776	12			698–806	Free	APCO 25 (764–806)
	794–806	12					
800 MHz Band	806–821	1.75				GSM and CDMA	APCO 25 (806–870), VIN(900, 1800),BRCK(850)
	821–824	3					
	851–866	1.75					
NPSPAC band	866–869	3				Public Safety	Trunked radio system
4.9 GHz band	4940–4990	50				Radio navigation	VIN mini

Table 2 Different known technology standard and their specification and related application field

Technology	Used for	Robustness/availability/security	Coverage radius	Required intermediate node	Operational scenarios
Analog PMR	Voice only	Limited	2 km	No	a,b,c,d
DMR	Voice and Limited Data	Limited (security)	2 km	No	a,b,c,d
APCO25	Voice and Limited Data at (20–30 Kbit/s)	Yes	Fixed cellular network	No	a,b,c,d
TETRA V.1	Voice and Limited Data at (20–30 Kbit/s)	Yes	Fixed cellular network	Yes (with repeaters)	a,b,c,d
TETRA V.2 (TEDS)	Voice and Limited Data at (120 Kbit/s)	Yes	Fixed cellular network	Yes (with repeaters)	a,b,c,d & e
TETRAPOL	Voice and Limited Data at (20–30 Kbit/s)	Yes	Fixed cellular network	Yes (with repeaters)	a,b,c,d, & e
GSM/GPRS/UMTS/3G	Voice and Data at (Mbit/s)	No	Fixed cellular network	Yes (with picocells)	a,b,c,d, & e
LTE	Voice and Data at (10 Mbit/s)	Limited	Fixed cellular network	Yes (with picocells)	a,b,c,d, & e
Satellite Networks	Voice and moderate Data at (100 Kbit/s-1Mbit/s)	Yes	Ubiquitous	No	b,d
WiFi/WiMax	Voice and High Data at (Mbit/s)	No	Local (300 Meters)	Optional	a, b, e
Ad-hoc Networks	Voice and High Data at (Mbit/s)	Limited	Local (up to 1 km)	Optional	a, b, e
Marine Communications	Voice and Limited Data for specific applications	Medium	Up to 30–40 km	No	b,d
Avionics Communications	Voice and Limited Data for specific applications	Medium	Up to hundreds of Km	No	b,d
D2D communication	Voice and Limited Data for specific applications	Limited	Up to 100 mtr	Optional	a, b, d, e
MANET	Voice and Limited Data for specific applications	Limited	Up to 1 km	Optional	a, b, d, e

- Manage Spectrum sharing through cognitive radio
- Provide Integrated Services
- Provide Security and Reliability
- Network should be Scalable and reconfigurable
- Real time Communication and response
- Efficient Energy consumption
- Resilience/Availability of the networks

There are different sets of standards have become predominant: TETRA (Terrestrial Trunked Radio), TETRAPOL (i.e., European standards) in Europe and APCO 25 in USA (i.e. an US standard) and TEDS. The different sets of standards are discussed in detail.

2.1 TETRA

TETRA is an infrastructure-based network designed on the basis of PS operational requirements. The key services of TETRA include voice and data-based application which support conference call among multiple users, Tele-services and bearer service which includes individual call, group call and broadcast call with interoperability among various standard. TETRA also provide supplementary services like bearer service or Tele-service on the basis of access priority.

2.2 TETRAPOL

It is basically a short-range based digital mobile radio for group communication, offers mainly voice and data services including public switch telephone network (PSTN) services through interfacing.

2.3 APCO 25

It is an infrastructure based fixed network standard thus the coverage is also limited like the above two standards. The Four key objectives which are mainly defined for APCO 25 standard are as follows (1) Provide enhanced functionality (2) Improve spectrum efficiency (3) Open Systems Architecture through multiple vendors and (4) Allow efficient, effective and reliable intra and interagency communications. APCO also support compatibility with legacy radios. APCO 25 also provides an enhanced set of services like TEDS including group calls, messaging and broadcast call.

2.4 TEDS

This is basically a new release of TETRA where digital modulation like 4, 16, 64 QAM and enhance bandwidth are adopted on priority to provide enhanced packet and data services. In designing the physical layer, and the higher layer protocols special care has been taken for compatibility with the existing TETRA protocol.

2.5 Satellite NEtworks

The operation of a satellite network does not depend on the existing terrestrial/infrastructure-based network; at the same time, it comes with the advantage of high coverage and mobility. Those enormous benefits of satellite communication make it very suitable for disaster and emergency communication. The terminal of satellite communication is of small aperture and even comes in the hand-held mobile device. Use satellite-based system for high bandwidth multimedia services like video streaming are in increasing demand [8]. Satellite communication for IoT applications and group communication with improved QoS is discussed in [9]. With little compromise in energy efficiency, satellite communication is able to provide a data rate in the range of certain megabytes and seamless connectivity to a non-reachable affected geographical area.

Satellite based future communication can be the only solution for providing immediate and rapid support to the disaster zone because most of the backbone networks are all infrastructure-based architecture. A rapid deployable satellite-ground emergency mesh network that offer high data transmission bandwidth in post disaster is modeled in [10]. The energy consumption in satellite nodes is high for due to frequency of operation and long-distance communication. Intelligent solutions regarding energy consumption may be taken through Ad-hoc network, where master node is selected based on residual power on the device. A satellite based hybrid infrastructure network is presented in [6], where author discussed the hybridization of terrestrial network with the satellite network on the platform of hybrid mesh protocol of wireless communication. The usefulness of satellite in post disaster phase is well deliberated in [7].

Emergency communication based on the satellite has become popular for its enormous benefits, ETSI is one of the standardized body governs the use of satellite communication for emergency use. The concept of emergency communication cell over satellite is discussed in the technical report of ETSI [11]. Which is basically a temporary network formed to operate on both wired and wireless standards for reliable communication employing bi-directional satellite link.

Despite its enormous advantage, the uses of satellite communication have counted limitations. Highly expensive, energy inefficiency, unable to handle simultaneous calls, and applicable for only short time use are some of the major limitations of satellite communication. Although advancement in technology reduces the limitation through terrestrial GSM service [12]. SLICE: Satellite communication-based project using a re-configurable and integrated Navigation and Communication (NAV/COM) device was proposed to enhance the localization and communication service in disaster [13]. To enhance the performance of satellite navigation, a GPS and other augmented system-based satellite navigation techniques are discussed in [14]. Hybridization of LTE communication network with the satellite service is presented in [15], where author discusses the provision of providing LTE service to disaster effected zone/users with the added reliability of satellite communication network. This gives the enhanced feature of hybridizing the infrastructure-based service to infrastructure-less service. Merging the features of LTE and satellite communication for effectively serving the emergency user was discussed in [16].

2.6 Digital Mobile Radio

The limitation of professional mobile radio is overcome with the enhanced feature of DMR which is proposed by the ETSI [17]. As per the frequency planning of the nation, DMR can be operated in any mode (licensed or unlicensed) of band between 446.1 to 446.2 MHz.

In comparison to analog PMR, DMR provides a higher data rate, improved range, improved battery life, and spectrum efficiency. DMR can be commission to work with any spectrum so there is no need for any further allocation of the spectrum or relicensing.

The development of DMR is based on three 'layers':

1. Layer 1 is the license-exempt low-cost digital PMR.
2. Layer 2 is for the licensed peer-to-peer mode and repeater mode service for professional market.
3. Layer 3 is for licensed trunked operation.

DMR also fulfills all the criteria of PS operational requirements mentioned above and can be used in any scenarios describe for PS organization above because of its infrastructure less operation.

Technology advancement in wireless communication gifted us many effective disaster communication solutions like instant networks and battery power networks. Instant network is effective as it requires no backbone network infrastructure and can be installed and on-air in considerably less time. Vodafone Instant Networks (VIN) and Vodafone Instant Network mini are examples of an instant network. On the other hand, BRCK (battery powered modem/router), is considered the most effective solution for providing internet service to the people of rural area in infrastructure-less environment. The detail working and description is given below The VIN is focused on large scale relief operations but the BRCK focuses on providing network access to individual. The VIN mini, which is comparably smaller than the size of a rucksack (bag), provides wireless access in hard to access environments. The detailed information related to disaster network is provided below.

2.7 Vodafone Instant Networks (VIN)

VIN is designed to provide relief service on large scale, where an extremely portable GSM module of weight near about 100 kg and can be used to cover an area of 5KM radius. After the disaster hit, VIN is easily installed in the affected area through car, transport vehicle, and flight, such that the relief network can be easily set-up in considerable time. In [18], author discussed the emergency networks using VIN and estimate that it can be possible to set up the network within few minutes of arrival on the site. The major component of VIN includes BTS (Base Transceiver Station) unit, battery bank, a rectifier set for converting the portable generator output to DC power and an RF antenna.

2.8 Vodafone Instant Network Mini

To serve the areas which are very difficult to reach, Vodafone with Huawei and Telecoms Sans Frontiers design Vodafone Instant Network mini. Which is portable, weighs around 11 kg, and comes in a backpack such that a single person could carry and install that at an emergency location. VIM could cover a radius of 100 m and uses the satellite link to host the network. The testing of the VIM is already done and practically used for deployment since 2014 [19]. Despite its enormous advantage, it has some limitations like handling 5 simultaneous voice calls and support only a low data rate 2G voice and SMS service.

2.9 BRCK

It's a battery power modem designed by Ushahidi, Kenyan-based Company for long time service to the disaster affected user. BRCK provides approx. eight-hour seamless service of Wi-Fi, 3G, and 4G service to the user located at the frequent outage zone. The most attractive and effective feature of BRCK is its portability, one person can easily install that to an affected zone at the time of disaster [20]. It uses 10/100 Mbps wireless standard of IEEE 802.11 b/g/n LAN/WAN for WI-Fi service and uses WEP, WPA/WPA2 PSK encryption technique for security purpose. BACK support quad band of 2G service containing frequency of 850, 900, 1800 and1900 MHz band and 3G service in the frequency band of 900, 1900 and 2100 MHz. BRCK service operating device is integrated into the device such that the service can be used at the time of need without any licensed SIM card.

3 Potential Future Wireless Communication Technologies for Disaster Scenario

A. 5G in disaster management with the advent of MIMO technology and device to device communication
B. Mobile Ad-hoc Network (MANET)
C. Self-Powered Wireless Communication Architecture (SPWC)
D. Cognitive Radio (CR) and Software Defined Radio (SDR)
E. Indoor Positioning System.
F. World Wide interoperability over microwave access (WiMAX)
G. Wireless sensor network (WSN)
H. Wi-Fi

A. 5G in disaster management with the advent of MIMO technology and device to device communication

The fifth generation (5G) communication network is famous for its improved capacity, reliability, robustness, and latency towards model an efficient network for disaster communication networks. 5G technology with advanced Network Function Virtualization (NFV) counts to be very effective for network resource management. On the other hand, Device-to-Device (D2D) communication is also found to very effective for resource management through offloading BS traffic load. Using Cloud Radio Access Network (C-RAN) of 5G communication how the performance of PS network can be improved is discussed in [21].

The inter-cell interference is an unpredictable obstruction toward achieving the desired goal of an ultra-dense communication network of 5G and beyond [22]. The use of Aerial Base Station (A-BS) such as UAV in conjunction with existing terrestrial BS may lead to inter-cell interference. Thus to overcome this issue with improved coverage and data rate, an optimal RAT selection and association strategy is discussed in [23]. For practical implementation in 5G and beyond communication, analysis is also made on the coverage probability and data rate while considering the height and density of A-BS deployment. A multi-agent reinforcement learning based self-learning interference mitigation (SLIM) scheme is proposed in [22] to mitigate the inter-cell interference by smartly handle the downlink transmit power of SBSs.

On the other hand, Machine learning algorithms are found very effective to tackle the congestion issue of ultra-dense 5G network in emergency. Machine intelligence plays a vital role in handling multi-dimensional and vast volumes of occasional data generated in the network. Furthermore, machine learning algorithms are useful for efficiently discovering the evacuation route for the victims and analyzing the diverse social data for accurate escalation of the information and rescue operation [24].

One of the key benefits of 5G and beyond technologies towards setup of emergency communication is its self-controlled strategy in establishing a connection with D2D communication. D2D communication provides several benefits like improving spectral efficiency, improve data rates and coverage, and higher energy efficiency can be achieved. Research in the domain of D2D got attention from the last decade. As discussed, it is basically implemented to reduce the traffic load of the main backbone network, thus to reduce the traffic load of LTE backbone network a cloud network that works on the platform of SDN is proposed in [25], which helps in the improvement of energy efficiency.

To off-load the BS traffic at the low SNR zone a cloudlet is proposed in [26] and FlashLinQ is proposed in [27], those are OFDM based synchronous network design to improve the gain characteristics of IEEE 802.11. Whereas to improve the security characteristics of the network and application, the diverse implementation scope of D2D communication architecture is deliberated in [28].

A hybrid network comprising of an existing cellular network with a D2D network is being popular for effective disaster recovery. In article [29], the author proposes a hybrid network with the D2D and terrestrial infrastructure based system, which promises to provide a packet delivery ratio of 98%. In [30], the author performs the analysis based on the usage of the D2D network in the co-operative framework through energy harvesting relay node to assist UE in disaster-prone areas.

A cluster centered D2D network architecture which integrates cellular and Ad-hoc network based on their availability is discussed in [31], Where a D2D communication as an LTE underlay network is being used for harvesting the proximity, reuse, and hop gains. In [32] the author proposed an architecture that enables PPDR services within an LTE based dedicated and commercial network. With the up-gradation in technology, researchers find the application of D2D communication in LTE networks for reliable and flexible disaster communication. In article [33], the author presented an opportunistic network deployment framework, where D2D communication network is established under the presence of LTE communication network, and in the absence of a network, deployment of Zigbee communication is considered for MT's battery consumption. It is observed that cooperative D2D discovery approach efficiently utilizes the LTE network spectrum using spreading technique [34].

In article [34], author proposes a hierarchal D2D communication architecture for providing LTE network in infrastructure-less situation whereas a Wireless Sensor and Actuator Network (WSAN) is formed with the SDN topology to improve the network efficiency and scalability [35]. In [36], a geo-location-based WiFi and inter D2D communication is presented, where a centralized hotspot is located in such an area that an accurate global map can be created to discover each and every device position comes under that hotspot vicinity. Whereas in [37], author proposes to incorporate a disaster mode into all mobile phones and developed a novel algorithm to facilitate D2D communication in an ad-hoc environment. Such that with the help of this particular mode users can communicate at the time of disaster. Based on D2D communication paradigm, a disaster resilient multi-hop D2D communication network is proposed in [38], which offers shortest path routing based scheduling in terms of user coverage in the affected disaster area. Whereas an effective mobile synchronization protocol is developed for establishing a synchronized mobile network to provide enhanced coverage in public safety communication [39]. This synchronization protocol works on the assessment of signal-to-interference-plus-noise ratio to assist D2D users in forward timing signal.

As Drone/UAV operate as a supplementary network in emergency communication to fulfill the vital need of public safety service. Thus utilizing Drone for broadcasting emergency alerts through D2D aided multi-hop network is discussed in [40], where a multi-hop multi-cast D2D assisted network is established for broadcasting the emergency messages to the victims. To minimize the post disaster congestion in the deployed UAV network, vital network contents are cached and served toward D2D aided victims with cache-enabled rescuers [41].

In D2D communication limitation: authors in [42] discussed how to wipe out the limitation of D2D communication with mm wave by forming ad-hoc network. Furthermore, One UE in D2D communication went through a large number of signal processing mechanisms while establishing communication through nearby BS and available D2D pairs. Thus, UE must be enough energy-efficient to sustain itself and establish a resilient and reliable communication network [43]. Thus authors in [44] present a D2D based emergency network while ensuring efficient use of UE power.

Failure of communication networks raises the scarcity among the people while relying on a particular service in event time. In [45], authors proposed a failure resilient approach by efficiently orchestrating network slices in a multi-connectivity 5G network while assuring a stable communication link. Dedicated network slice for catering the diverse essential services provide enhanced flexibility to emergency communication [46].

B. Mobile Ad-hoc Network (MANET)

Mobile Ad-hoc network is a promising technology for public safety communication due to its infrastructure less setup. MANET proves to be vibrant, self-governing, and less complex in setup of emergency communication and rescue operation at the time of disaster [47]. MANET is a form of a network that can move with the user terminal, and the network configuration adaptably re-configured with the active user location without any infrastructure [48].

In the setup of a highly reliable communication framework, MANET could be an optimum choice. In this regard, MANET based emergency project 'WIDEN' deliberated real-time communication service in emergency [49]. On the other hand, The DUMBO project deals with the lightweight moveable mobile nodes to increase communication service coverage for remote areas. The proposed scheme analyze the extension of wireless mesh network coverage utilizing hybrid Wi-Fi and satellite connectivity and promise to deliver the communication service to the place which is not accessible by road and where the network is either destroyed or not present [50].

Routing protocol plays a significant role in the performance of MANET. In article [51], author proposes a protocol for MANET, namely Dynamic Connectivity Factor Protocol (DCFP), and observed that the proposed algorithm has a remarkable advantage over AODV and Neighbor Coverage-Based Probabilistic Rebroadcast (NCPR). A novel DNS-based Service Discovery for disaster recovery system is modeled in [52], which promises to provide a minimum delay of 100 ms. The delivered service includes communication, sensing and data processing, etc., for a mobile device, PDA, etc.

Features which fits MANETs for emergency communications are as follows.

1. Multihop Communication
2. Infrastructure less
3. Dynamic Topology
4. Network Scalability
5. Short range connectivity

Here we deliberate the application of MANET considering the three phases of disaster that are before (pre), in time (in), and after (post) disaster.

Pre-Disaster Communication: The pre-phase of disaster mainly deals with the warning system and alertness. In this phase of the disaster, network system basically works on the three stages namely (1) sensing/detection, (2) alert/warning, and lastly (2) find a suitable solution for the preparedness. In [53], author discussed the different sensing schemes for the prediction of disaster.

Post-Disaster Communication: After a disaster, numbers of hops of the backbone network get hampered, so to provide an immediate solution for blackout zone MANET comes into the scenario. With MANET, temporary mobile UE to UE connectivity can be established by relaying the intermediate terminal. Lastly, connection with the core network can be managed to establish by satellite or large size MANET cluster [48].

The formation of a hybrid network with the existing network is being an efficient solution for post-disaster situations. In post-disaster scenario, formation of an efficient communication network with the existing topology considered to be an ideal choice. Formation of Heterogeneous Network (Het-Net) with ad-hoc and the existing sparse BS is considered in [54], whereas formation of Het-Net with ZigBee and Wi-fi for the extension of coverage of existing wireless communication network is discussed [55].

In- Disaster: To improve the energy and throughput efficiency of the mobile device hybridization of the routing protocol get popularity, in hybrid routing protocol key advantage of the two routing protocol is merged for the enhancement of the sum characteristics of the design protocol [56].

In the deployment of rapid emergency communication in high-rise buildings and structures, a GIERS is proposed based on GIS system [57], which has the potential to provide safety after a terrorist attack. Usages of handheld and portable device for emergency communication becomes possible for MANET. In this regard usage of a personal computer in emergency communication through establishing a P2P net was discussed in [58]. To resolve the frequently arises problem in communication among firefighters, an impartial mobile application based on a cellphone is developed and discussed in [59]. After that to find the shortest and suitable route for disaster victim to escape from the zone an application name MyDisaster is proposed in [60], which facilitate easy and fast route selection for the disaster victims. Relevant research finds attraction is the development of Context-Based Location Management (CBLM) [61] which facilitate mobile agent to discover the feasible and suitable route. To improve the location management, network data rate should be fast to facilitate smooth map management, in this regard integrating both LTE and MANET networks for featuring battlefield soldiers is discussed in [62].

In the same way, improving spatial communication by combining the features of paper maps and handheld mobile devices in mitigation of crisis response is discussed in [63]. Based on mobile electronic triage tags a fast responder system is analyzed [64] for fast medical facility arrangement to the disaster victims located far from the operation base. To support disaster victim and rescue team crew in communication should be the prior task of any emergency communication, in that regard Disaster Recovery Networks (DRN) and Search and Rescue Network (SRN) is proposed in [65], where DRN basically designs for setup of disaster communication network and SRN designs for exploration of optimal path and rescue network.

With the growing traffic in the communication network, mobility management keeping the QoS demand is a serious issue [66]. The effect of node mobility in secret covert communication is analyzed in [67] by throughput scalling over the wireless ad-hoc network. In establishing secure communication through ad-hoc network, authors in [68] introduced an event chain mechanism for secure payment in disaster to prevent the double-spending attack. In [69], authors present a novel and intelligent packet forwarding approach for reliable communication based on the game theory to meet the network Quality of Services (QoS) requirements.

The Evolution of Multihop Ad Hoc Networks:

3.1 VANET

MANET could not be relocated and move to the disaster location quickly. To overcome this problem, an evolution of MANET called Vehicular Ad-hoc Network (VANET) is developed to acquire the desired movability [70]. In VANET transceiver is installed on the vehicle, and which is move on traffic road for finding the required zone. The main motive behind the design of VANET is to provide mobility and quick setup of communication in the desire location. VANET could come in the application field of disaster communication by its immense features like emergency rescue vehicle connectivity, road navigation, and traffic offload to the main communication network. VANET, with the added features of software governance, effectively improves the flexibility and robustness of the rescue service [71]. On the other hand, the enormous development in the smart android stereo/infotainment of vehicles makes it more suitable for emergency applications. An android application based live emergency alert model is proposed in [72], which offers efficient and safe driving to the vehicle while establishing reliable VANET.

One of the major drawbacks of MANET like limited power backup can be mitigated in VANET, as the power supply to VANET could be managed from the vehicle fuel-generated power.

3.2 Wireless Mesh Network (WMN)

WMN is almost similar to MANET in respect of connectivity and operation, however, the differences are in the design of routing protocol and application scenario [73]. The rigidness of Local Area Network (LAN) could be minimized with the wireless features of

WMN. With WMN the internet connectivity could be managed to provide to the disaster victim at the edge of the network where no infrastructure is available.

Wireless technologies like WiFi and WiMAX are considered as the main suitable candidate for WMNs. WMN can be considered as a mechanism for rapidly deploy an Adhoc network. In [74], a WiFi-based mesh network SKYMESH is proposed to provide fast internet access to a disaster affected zone where transceiver WiFi access point of WLAN deployed on helium balloons to form a wireless mesh network. Similarly, multimedia service can also cater to the disaster effected victim through the deployment of WMN is discussed in [75], where hybridization of MANETs, WMNs, or even WiMAX is done to form a mesh network and enlarging the service area through a satellite communication link. This helps two far mesh network zone to communicate with each other at the time of need.

3.3 RFID

Radio Frequency Identification (RFID) is a device-to-device communication technique used for the rapid build-up of authentic network and initiation of information sharing, and identification. In systems come with RFID reader and tag, tag contains the authentic information of the user and the reader used to read that information from the card and initialize the communication such that authentic users get access to the system and work accordingly. The use of RFID in emergency scenarios is discussed in [76]. The Near Field communication (NFC) in a smartphone is an advanced form of RFID technology, where through establishing ad-hoc networks users can perform local communication.

RFID technology is mainly finding its application in the pre and after disaster phase for localization and place assessment. In disaster area surveillance, after the occurrence of disaster RFID based building assessment system is proposed in [77], which helps the in-building and rescue team to get the proper knowledge of the building condition before starting any operation. RFID based building indoor area localization [78], and disaster effected victim localization [79] are discussed in details in the area localization paradigm and effective disaster area surveillance. RFID-based indoor area localization is getting popularity and attracted researcher's attraction due to the absence of GPS signal at the indoor scenarios [80]. An RFID based disaster recovery system, namely RESCUE is proposed in [81], which helps to find the trapped people in building due to disaster. RESCUE is a wireless power backscattering communication system used to provide essential geo-location as well as victim's number data to the rescue team.

3.4 DTN

MANET faces the problem of getting disconnected frequently due to node movement which is being overcome by the Delay Tolerant Network [82]. In recent times, the classical MANETs are being evolved in the form of DTNs [79]. For communication between two nodes of a DTN, there need not be high connectivity but rather a carry-store and forward model is followed. The nodes generating information store it before delivered appropriately upon meeting other nodes. Due to these features, DTNs being called Opportunistic networks as the interaction between nodes creates opportunities for information delivery. Novel approaches for forwarding information in Delay Tolerant Networks (DTN) for disaster communication have been discussed as follows. In [80], PropTTR and PropNTTR are proposed as opportunistic protocols that efficiently utilize energy. In [83], the authors vouch for a forwarding protocol that handles messages on a priority basis. The works discussed [84–88] discuss how DTNs can be utilized to handle crises effectively.

A DTN based using electronic triage tag, Haggle, and mobile devices for communicating information about victims during disasters has been proposed in [84]. In [86], a guidance system for victim evacuation has been presented. This system enables the evacuees to be able to collect useful data in their surroundings like road blocks, safe passages, or the locations from search and rescue agencies and share it over an opportunistic network. Both [87, 88] have put forward systems based on cognitive wireless networks and an evolved media-coordinate system that promotes the enhanced working of DTNs in disaster conditions in remote and rural locations.

In [85], a system called Distress Net has been proposed, where a system aids the Search and Rescue (SAR) attempts in the aftermath of any disaster. It is a complex system incorporating DTNs in addition to WSNs and MANETs. The system allows victims to use a storage system similar to cloud storages to store and access data. The members of SAR parties can use handheld devices like mobile devices or tablets for data monitoring or collaboration among various teams. The data is being generated by numerous sensors deployed over the affected area for monitoring purposes and to find potential survivors. This data is also relayed over the DTN to the command center for control and monitoring purposes.

In [89], an opportunistic network suited for urban SAR operations has been presented which involves a network of sensors for data recovery from disastrous conditions. A working prototype communication model that combines both MANET and DTN for ad-hoc communications in the event of any disaster approaches has been presented in [90]. This model requires a mobile application for switching between the modes. It uses OLSR protocol for routing in the MANET mode whereas, in the DTN mode, the epidemic forwarding protocol is being deployed.

To be able to switch between modes, the nodes identify and use various device (smartphone) parameters like its battery level, accelerometer, and its surroundings (density) for the right choice to be made. In the aftermath of any disaster occurrence, only being dependent on a cellular network is not secure, particularly for a SAR operation team due to their constantly changing location. The authors in article [91] address this issue by proposing a vehicular DTN which forms a vehicular cloud and thus, overcomes the disadvantages of a cellular network in affected areas (Table 3).

C. Self-Powered Unmanned Aerial Wireless Network

Self-sustain, economical and fast deployable infrastructure less network is considered as a prominent solution for disaster relief operations [92]. Low Altitude Platform (LAP) is considered as most suitable platform for this purpose as because of low propagation loss. Self-Power Wireless Communication (SPWC) architecture is chosen to mitigate the most occurred issues of disaster relief and rescue operations.

Mainly two types of communications method used for connecting the event zone people to the backbone architecture, first one is Air to Earth Communication scene where UAVs are communicating with mobile terminal through 2G, 3G or 4G. Secondly one is the UAV-to-UAV Communication where the network among the UAVs are established through mesh network.

To mitigate the often-occurred issues in the wide disaster network, a self-power wireless balloon architecture for disaster relief operation is proposed by the authors in [93]. This

Table 3 Comparison data regarding the mobility, expected density, wireless technology, topology, routing protocol and functionality of MANET and all evolved Multi-hop Ad Hoc Networks

Ad-hoc paradigm	Mobility	Expected density	Wireless technology	Topology	Routing	Main functionality
MANET	Low-medium Unexpected	High	WiFi (IEEE 802.11a/b/g) Bluetooth (IEEE 802.15.1)	Changeable Flat	Broadcasting schemes Routing protocols (Network layer)	Real-time communications
VANET	High Predictable and constrained by lanes	Medium–high	DSRC (IEEE 802.11p)	Changeable Flat	Broadcasting schemes Routing protocol (Network layer)	Real-time communications
DTN	Medium Unexpected	Medium–low	WiFi (IEEE 802.11a/b/g) Bluetooth (IEEE 802.15.1)	Changeable Flat	Forwarding schemes (Bundle layer)	Communications for non-delayed sensitive data
WSN	Low	High	ZigBee (IEEE 802.15.4)	Fixed Hierarchical	Broadcasting schemes Routing protocols (Network layer)	Detection and warning systems
WMN	Low	High	WiFi (IEEE 802.11a/b/g) WiMAX	Fixed Hierarchical	Broadcasting schemes Routing protocols (network layer)	Backbone network
RFID	Very low	High	NFC	Hierarchical	Point-to-point	Identification
TETRA, TETRAPOL	Medium Tactical	Medium	Private (similarities with GSM)	Changeable Flat and hierarchical	Point-to-point Point-to-multipoint Repeater	Real-time communications

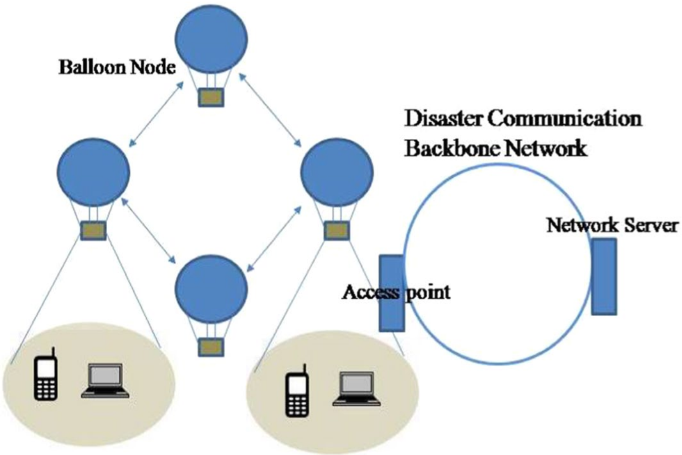

Fig. 1 Wireless Ballooned Network for disaster relief

wireless ballooned architecture is found to be very effective in the delivery of communication service to the victim situated in the non-accessible zone.

The proposed architecture utilizes self-power balloon equipped with solar panel and additional small battery for power supply. Analysis depicts that it is very promising for long time service to the disaster effected zone with the formation of inter balloon ad-hoc network.

Figure 1, gives a visual idea of the self-powered wireless ballooned network, where wireless access point is compiled with the balloon to make it flying node and while connected with the other same node, a mesh structure of flying nodes is form to cover

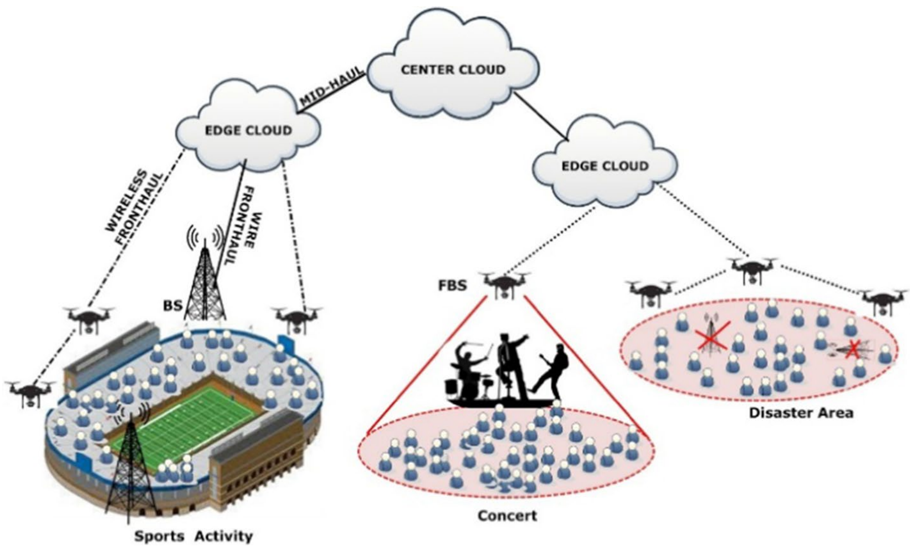

Fig. 2 Application of UAV based network for maintaining QoS over hotspot area

a geo-graphical area of consideration. The significant limitations of this architecture are limited energy of the nodes, and at least one of the nodes should have the connection with the core backbone network to establish communication. Author in [94] discussed about the energy constraint of the UAV, where author proposes a novel UAV aided data collection algorithm namely ECO-UDC, which reduce energy consumption of wireless transmitter by 30–40 percentage.

UAV aided communication is very helpful in disaster scenario for the collection of rescue information, shelter information, relief goods information, etc. To work efficiently these UAV have to locate optimally, in article [95], the author focuses on the placement of unmanned aerial base station that can be a part of Heterogeneous-Network where genetic algorithm is used to optimize the location of UABs. In [96], author proposed an aerial Adhoc network based on Jaccard dissimilarity metric, where the UAVs are deployed by self through maintaining a distance close to a Jaccard threshold such that each UAV will be affected by only two nearby UAVs with lowest Jaccard distances with respect to it.

Recently, Unmanned Aerial Vehicle (UAV) is considered as an appealing technology to set-up an on demand, fast deployable and cost-effective wireless network over the hotspot. Owing to its autonomy, mobility, reliability and flexibility, the UAV-based network is inevitable for various application in telecommunication like set-up emergency communication, act as relay, data offloading, and maintaining QoS over a densely populated area like concerts, fest, and stadium (Fig. 2) [97–99]. UAV, alternatively known as Flying BSs (FBSs) has the ability to adjust its position to avoid obstacles, and improve the Line-of-Sight (LoS) communication links to ground users.

Beyond 5G/6G communication is estimated to provide ubiquitous and seamless connectivity to ground user to fulfill the desired need in any circumstances. The exponentially increasing demand of high data rate services need an intelligent network which could efficiently cater the service on-demand. In this situation, UAV aided network as shown in Fig. 2, is treated as an optimum choice to serve the sudden raises demand of high QoS and high data rate service. UAV based services got the attention from the industry for building emergency and public safety network due to recent advancements in technology and some of unique inherent advantages of UAV. In emergency and high gathering events where network traffic boosted suddenly, existing cellular network is not design to handle such network calamities due to limited coverage and capacity [100].

UAV promises to be an alternative solution in providing wireless network coverage for surveillance and rescue in a disaster affected area. The application of UAVs as a mobile sensor node are also a promising area of potential research and development [101, 102]. There are good numbers of work done on the deployment feasibility of UAV in the low altitude platform but still there exist many challenging issues that are yet to be addressed for a fully functional UAV wireless network. In [103], Al-Hourani et.al provides a mathematical model for optimal altitude of the low-altitude aerial platforms through providing maximum coverage in a considered geo-graphical area. The analysis depicts that the optimal altitude is a function of the maximum allowed path loss and statistical parameters of the urban environment. In [104], the authors elaborated the transport theory for optimal UAV deployment where energy efficiency of UAV is considered as the key constraint for providing long time service in a specific geographical area. In [105], a closed form expression for optimal probability of Line-of-Sight (LoS) connection between a Low altitude platform (LAP) and a ground user is developed where the optimal altitude of a drone small cell (DSCs) is also derived in order to maximize the cell coverage as shown in Fig. 3.

To extend the coverage of the UAV aided network, intermediate UAVs are deploying and work as a wireless communication relay node. Thus, for capacity maximization of the

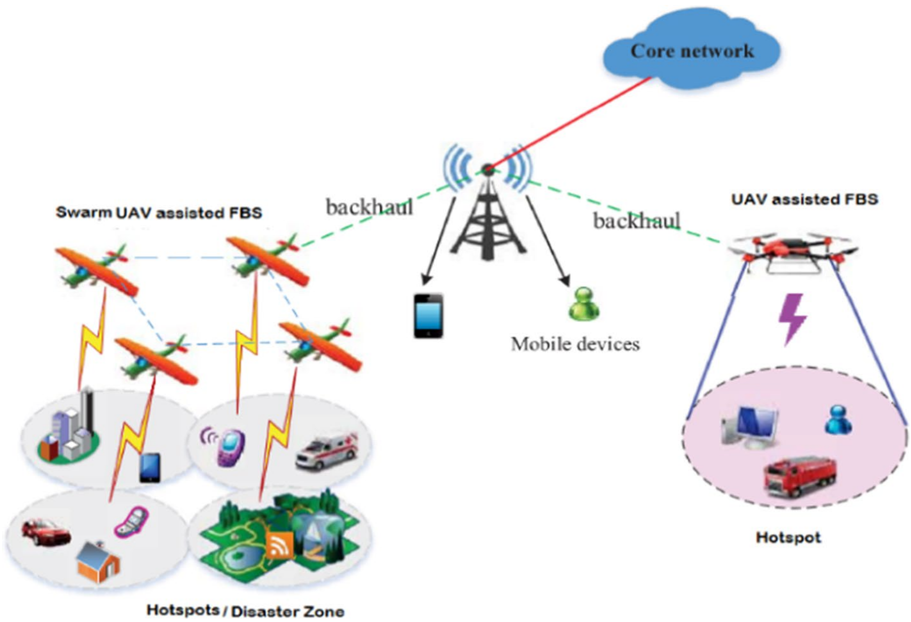

Fig. 3 UAV aided Flying BSs to serve the user of target area

wireless network, formation of a large UAV aided network is the alternate solution to provide reliable communication service to the ground user [106]. A comprehensive literature on empirical formulation of air-to-ground channel modeling in UAV communications is deliberated in [107, 108]. An innovative approach for air to ground channel model in low altitude platforms for UAVs like drones and quad-copters is discussed in [107]. The alteration of height in optimal UAV planning is an important factor under the constraint of coverage and capacity. However, with the alteration of UAV height two issues may occur, (1) the coverage radius will vary and hence the user association, (2) the path loss factor will vary and hence the SINR will change which causes data rate fluctuations leading to unsatisfactory QoS [107]. In UAV deployment height of the UAV plays an important role in UAV channel characteristics measurement due to the tradeoff between the LoS and the shadowing effect [108]. As with the increment in altitude of UAV LoS connectivity to ground user improves but path loss increases and vice versa. Therefore, an optimum altitude for which UAV provides maximum user coverage and association need to be investigated.

The deployment of UAV poses a serious challenge and needs careful design strategy in order to maximize the utilization of resources. In UAV planning the energy consumption and service period is highly related to the processing time required in running the optimization algorithm on board of an UAV. Authors in [109] proposed a method to find the positions of drone-BSs in a geographical area using particle swarm optimization (PSO) algorithm. But PSO based algorithm is time complex and therefore requires more time in finding the optimal location for deployment of UAV in any geographical area. Also, such algorithm is in-efficient to provide optimal number of drone BSs in a specified area for coverage.

PPDR (Public Safety and Disaster Relief) network aims to provide a communication service to a geographical area which may not be physically accessible. Thus to rescue thousands of life, the deployment of after disaster emergency network have to be very fast and high capacity [110]. Thus research investigation has the challenge to develop a fast and efficient UAV deployment algorithm. In [111], the authors have discussed about the processing time required in the planning of UAV and proposed algorithm based on K-mean (K-Cov), with K-mean and PSO (K-APSO), Lloyd and mean clustering (X-Cov) to find the optimal location of UAV in a considered area for user coverage. The authors have observed that the execution time required in the X-Cov algorithm is superior as compared to K-APSO. The basic geometric approach in X-Cov provides less execution time in computation of the location of UAV but fails miserably to find the optimal location of UAV in the solution space.

The evolutionary algorithm (EA) could also be used in order to find the optimal location of LAPs [112, 113] in an UAV network. In [114], authors proposed an analytical approach for the optimal location of a ground base station and number of relays needed in the network for maximizing the coverage. However, the authors did not consider UAV deployment issues in order to increase the coverage issue. In [115], the authors presented a drone assisted public safety broadband network by using DSCs as relay instead of ground based BS, but in practical which are difficult to place during emergency situations. In [104], the authors deliberated optimal deployment of UAVs and user association to static UAVs in order to meet the user data rate requirement. However, the dynamic characteristics of placement of UAVs in terms of height adjustment and spatial location are not addressed. Also fast deployment of DSCs in order to satisfy urgent network coverage is missing in the literature.

For any UAV based wireless communication system, energy consumption of the network plays an important role in order to sustain seamless connection for a longer period of time. In [116], authors proposed an analytical approach through clustering the ground users and provide a UAV for each separate cluster such that the consumption of energy by UAV for uplink communication can be reduced significantly. In [117], authors proposed a model to minimize the deployment time to cover the considered static geographic region such that the overall energy consumption of UAV can be reduced. However optimal user association and UAV deployment strategy is not investigated in literature. Fast deployment of UAVs in optimal locations is a decent approach for minimizing energy consumption during emergency communication. While mentioning the energy harvesting strategy of UAV-relay in forwarding the data with the adoption of SWIPT is discussed in [118], were to maximize the system throughput, a joint UAV trajectory selection and resource allocation problem is analyzed.

Failure of connection to backbone network is a common phenomenon in infrastructure-based network architecture during disasters, which causes serious problems in emergency rescue operations and restoration of normalcy in the zone. In [119], Merwaday et, al. proposed a solution for minimizing the blackout area by introducing Unmanned Aerial BSs (UABSs) and also investigated about the optimal number of UABSs to cover such blackout area under certain constraints. The major difficulties for public-safety and emergency communications (PSEC) can be resolved with speedy deployment of UAV. One of the serious problems in the PSEC is the sudden increase in network load due to abrupt assembly of users in a specific location at any instant of time. Such problem can be reduced by capacity maximization of the serving network by UAVs. In [120], Sharma et, al. worked on the capacity maximization of the heterogeneous network through UAVs. In [121] the authors proposed some methodology for accurate placement of the UAVs by optimizing the UAV assisted delay. In [95], the authors proposed multi-tier drone cell architecture for performance improvement of the heterogeneous network by providing additional resource and coverage on temporary basis.

Apart from minimizing energy consumption and finding out the optimal location of UAVs in any specified area, optimal trajectory path for deployment of UAVs to any intended location is a serious concern [122]. It is directly related to the performance of the overall system and hence should be investigated. In [123], authors worked with autonomous robots and have shown swarm movement of the robots without any centralized control. In [124], Jadbabaie et, al. proposed a time efficient deployment of UAV considering optimal trajectory planning in a 3D urban structure.

The optimal deployment of UAV is a complex problem in the present scenario where multiple UAVs have to follow different paths to cover different regions in an area in order to maximize the network utility function. Optimal deployment of UAVs as a drone BS for public safety operation is a promising and attractive approach [125]. In public safety and emergency communication, fast deployment of UAV confirming user density, data rate and area coverage is a challenging problem which needs to be addressed. Wireless resources are scarce and essential to utilize efficiently for effective communication. In [126], authors jointly optimizing the UAV's 3D location and resource allocation while improving the QoS requirement of each user in an emergency situation. In post-disaster rescue operation, the resource allocation problem is encounter by establishing human-UAV interaction felicitating Machine-to-Machine (M2M) and Machine Type Devices (MTD) [127]. Efficient resource utilization for UAVs by addressing the channel model is presented in [128]. For indoor communication in emergency, resource allocation by analyzing path fading model and outage probability is discussed in [129].

In UAV aided wireless communication, joint resource allocation and optimal deployment of UAV is considered in [130], whereas resource allocation and trajectory selection of UAV is discussed in [131] to optimally balancing the network resource and user coverage. Furthermore, optimal UAV trajectory selection could maximize the resource efficiency significantly [132]. On maximizing uplink throughput and energy efficiency of user equipment, authors in [133] presents a safe-deep-Q-network (safe-DQN) for UAV trajectory.

Despite such promising opportunities of FBSs, it brings several technical challenges need to be addressed for sustainable use. Deployment of FBSs over a hotspot area comes with many problem statements, such as finding the optimal 3-D location of FBS, interference mitigation, the total number of FBS requirements, and find a suitable strategy for user assignment to FBSs energy-efficiently and its QoS demand. The energy harvesting capability and wireless power transfer for sustained communication is also an area of great concern for 5G and B5G applications.

After deployment of FBSs, the set of other challenges that need to be addressed are the strategy for optimal resource allocation, synchronization, the decision on content placements, and find the cache memory size. Operation of FBSs under 5G standard brings a different kind of problem statement related to beam forming, Network slicing, and the decision of baseband functional splitting concerning latency, data rate, and battery capacity. Network security is the biggest challenge in UAV communication. There is a high possibility of data breach and hacking of aerial data by cloning of UAV or any physically hijacking. Secure UAV communication has many problem statements related to security key distribution, registration, validation, and data management.

D. Cognitive Radio (CR) and Software Defined Radio (SDR)

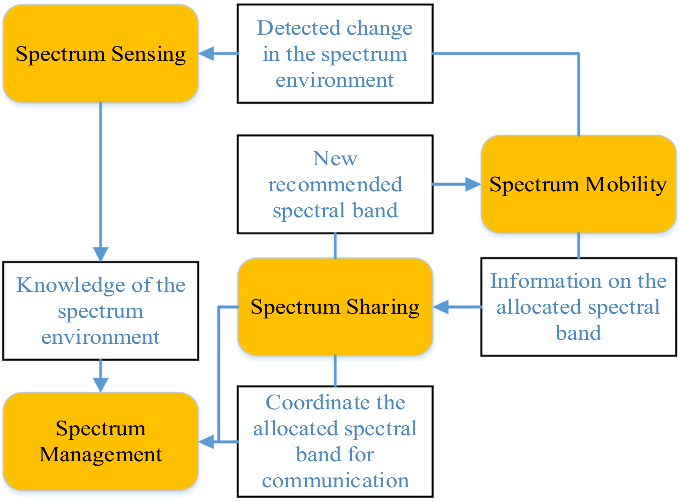

Fig. 4 Cognitive radio scenario

Cognitive radio is a transceiver that is aware of its RF and physical conditions and is able to make smart decisions based on its experience. The capacity to understand the network dimension specifically incorporates cognitive-communication technology in public safety and disaster management. The application of tiny autonomous aircraft cognitive systems, including sensors, tracks their surroundings and takes rational action.

Foundation stone of cognitive radio is laid by Joseph Mitola [134], investigated the architecture and implementation of the device. CRs are normally the following functions as shown in Fig. 4:

1. Spectrum sensing
2. Spectrum control
3. Spectrum exchange
4. Versatility of spectrum

Cognitive radio with this assistance has the versatility needed by one PS system for re-establish communication network. Authors in [135] addressed the application of the CR Network and spectrum allocation rules in emergency network and discussed how PS connectivity could be improved.

The implementation of CR in the PS domain was examined and discussed in various articles. In [136], the authors suggest the cognitive emergency radio approach based on the Multiple-Access Frequency Single Carrier Division (SC-FDMA) to allow the disaster network terminal to automatically scan for spectrum resources whenever feasible in the crisis region, e.g. not used.

In [136], the authors explain why the lack of availability of spectrum bands in the PS domain could be beneficial for cognitive radio. In [137], the authors describe how cognitive radios can support public safety operational capacities and emergency communication awareness, learning, and intelligence.

The use of public safety spectrum pooling was suggested in [138], where the author made the argument for emergency and general access network and spectrum sharing.

Authors suggests an immediate frequency allocation management Cognitive Policy Model (CPM) to regulate the spectrum management for disaster/emergency use. The article further outlines potential obstacles to this pattern being implemented. The future use of this technology in the area of public safety requires to be addressed in some respects.

The FCC released a letter in December 2012 proposing the spectrum sharing and small-cell use in 3.5 GHz band considering the PS standard [139], specifying spectrum regulation scheme and requirements for the use in PS. Radio spectrum use for common communication services was released by the European Commission in September 2012 [140], in which demands for public protection and disaster relief (PDPR) are specifically stated.

3.5 Software Define Radio (SDR)

Joseph Mitola has developed software-focused technology to design radio systems that describe hardware features through software [141], software-based radio [142], reconfigurable radio, and scalable radio architecture [143]. The operation of SDR is guided by the appropriate software for the required range of frequency, bandwidth, modulation technique, and data rate. Usually, SDR requires the waveform to be modified within certain boundaries, as the current system does. The simplicity offered lies in the use of multi-band and multi-modulation schemes.

The first Software Communications Architecture (SCA) in Vanu Inc.'s' Anywave' base station licensed by the FCC [144] is the SDR Computer Communications Architecture (SCA). In order to build a rescue service team support network that can cover certain specific functionalities, namely (1) Spectrum sensing and Auto mode identification; (2) dynamic multi-model reconfiguration, (3) Navigation, a novel concept influenced by Software-Defined Radios [145].

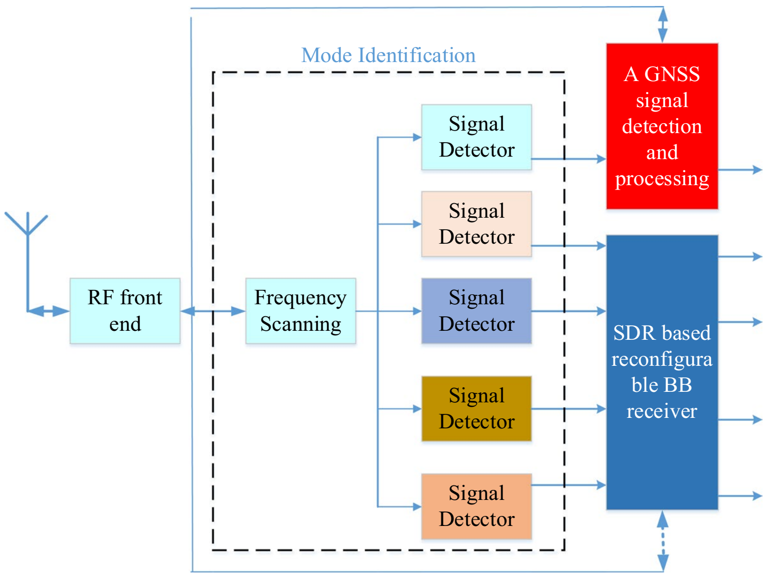

Fig. 5 Reconfigurable SDR based receiver

SALICE (The national research initiative of Italy) [13] was formed for learning and developing innovative ideas to integrate satellite communication with the terrestrial and positioning system into a single communication network governed by SDR technology. The work efforts of SALICE that have culminated in the implementation of a groundbreaking SDR approach based on a completely software operated smartphone is illustrated in [145].

In brief, it can be claimed that SDR can provide high flexibility and configurability in a more cognitive perspective, together with other benefits of a decreased size and weight of the terminal along with reduced power consumption [13]. In the suggested SDR-based approach, a transportable multi-standard terminal is built into the single box for GSM and UMTS base-station.

In order to detect all the signals coming from various channels, the RF front end should be dual-band. Thus designing a reduced size dual-band antenna that will support PS standard is a challenging task. The concept is a dual-band antenna of reduced size and weight for vehicle applications which will help to monitor GPS and terrestrial GSM signals are proposed in [146] (Fig. 5).

Relying only on conventional communication system may increase the possibility of network blackout. Thus an SDR-based reconfigurable and interoperable communication network is adopted to facilitate reliable public safety services in post disaster scenario [147].

To handle the enormous data generated from the different services of 5G communication, SDN plays a vital role [148]. SDN offers intelligent handling of different data services while ensuring essential parting between the control and the data plane [148]. In [149], authors proposed 5G-EmPOWER: An open platform for software-defined Radio Access Network (RAN), which enables multi-RAN (consisting of LTE and Wi-Fi) to operate under the same frame for improving flexibility and capacity of the network.

On the other hand, the improvement of smartness in WSN motes, enhance the applicability of WSN in various emergency and monitoring purposes through the Internet of Things (IoT). The communication performance of WSN is further improved through VERO-SDN: a software defines WSN for various IoT application [150]. SDN is designed to handle the various issues of IoT services; by reducing the complexity of IoT services, it helps establish an efficient emergency service provider [151].

A grid-based model to compute the traffic-congestion probability of the transportation network and a polynomial-time solvable algorithm is developed to reduce the link congestion probability in smart cities for IoT [152]. That proposed scheme promise to solve the congestion issues that arise in the IoT network of smart cities.

E. Indoor Positioning System

For traditional localization methods, mobile devices are essential for the effective location of outdoor positioning. On the other side, indoor areas usually require other forms of infrastructures, such as wi-fi access points [153, 154], acoustic beacons [155], and RFID tags [156], which can be personalized according to application.

Recently, a Wi-Fi-based indoor positioning system (IPS) is becoming popular due to its simplicity and robustness [157]. In Wi-Fi based indoor localization system, received signal strength indicator (RSSI) is used in the localization of fingerprint data. However, the RSSI based poisoning is not accurate and reliable because of multipath component of the wireless signal, blockage by obstacles, and shadow fading [158]. In [159], author proposed

Fig. 6 Architecture of real time indoor positioning system

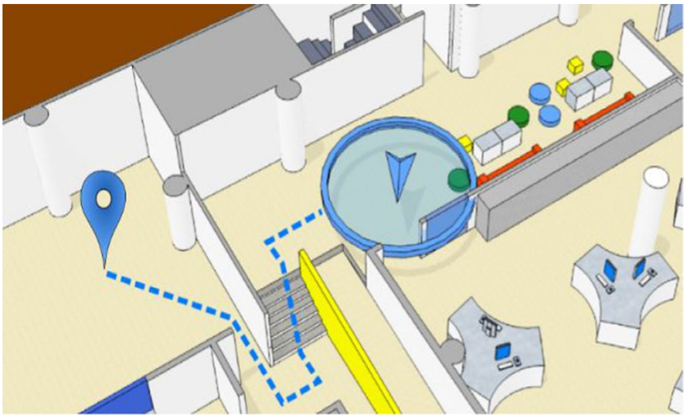

Fig. 7 Application based position estimation by using step detection algorithm

a non-RSSI based multi-dimensional clustering for access point optimization to find the indoor positioning. In [160], a C-means clustering based improved public c-means (IPC) is proposed to optimize the fingerprint data. With the advancement of swarm intelligence, a hybridized algorithm considering artificial neural network and swarm intelligence is presented in [161], which improves the reliability in positioning and reduces dependency on RSSI fluctuation.

The article [162] provides a model for the ETS program for first responders in emergencies. In this case, the embedded internal sensory of a mobile device gathers tracking information and makes it available to the consumer on the display screen via the user-friendly interface of the Android application and the Web Server framework for storing real-term tracking information. Here, authors modeled an indoor emergency positioning system in real-time scenarios for effective disaster communication, as shown in Fig. 6. Suppose the existing communication system does not work. In that case, the First Respondent user device establishes the communication to a portable communications unit (ComU), and that

ComU is responsible for communicating the signal to the rescue team. Figure 7 illustrates how android apps help the user to reach the target.

In [163], Ying et al. developed a detection method based on three steps for accelerator sensors. In this methodology, walking steps are evaluated after adequate processing of obstacles collision data and through managing acceleration adjustment while striking with obstacles. Authors in [164], present a new indoor positioning approach based on 868 MHz radio sites and inertial sensor data as a guidance system for emergency response personnel.

In [165], authors present a new indoor monitoring system for emergency responders, which is based on inertial sensors. That system device is composed of three parts: acceleration, angular rate, and magnetic field sensors. The first component is a modified Kalman filtering which performs fusion of sensor data while detecting and minimizing magnetic field disruptions to provide a permanent and long-term solution for exact passion assumption. The second part is the upgrading of zero velocity, which resets the speed to provide accurate location details in a stationary phase. The last and main part of the system is to monitor the movement of each body segment, accomplished by measuring each body segment's relative position dependent on a translation of each body segment's coordinate frame. The test results indicate that the device will track indoor people and observe body movement throughout the trial in both walking and running situations.

In a large building where general infrastructure-based localization is not working (e.g. because of management/installation costs, power failure, terrorist attacks), a Clisps integrated indoor positioning system that does not require any pre-existing interventions is design and implemented [166]. There are already firefighter positioning services, which use GPS receivers in conjunction with PDR [167]. PDR-type systems are used to detect steps, estimate step lengths, and estimate step direction by an inertial measurement unit (IMU), that contains accelerometer and gyroscopes, usually combined with magnetometers. Those IMU systems can achieve a location error below 2% of the distance moving in ideal conditions using back or torso-assembling IMUs (see [168, 169]). However, the position error is expected to be substantially higher during realistic first response operations [170].

Certain conceptual positioning schemes for the first responder to use IMUs assisted by other sensors include:

- GLANSER [171] using a Doppler radar on its rear firefighter, with the aid of PDR-type systems, with speed calculations.
- Chameleon [172] that uses double cameras (visual or thermal IRs) for inertial navigation. The system is built on a simultaneous mapping and localization system (SLAM) which also allows building maps to be created.

An alternate type of system which is currently under development and has become quite popular is the foot-mounted inertial navigation system (INS). Here the IMUs are assisted by zero velocity updates (ZUPTs). The foot-mounted INS devices are more suitable for practical first responder action due to their higher accuracy and robustness as per as the emergency communication and rescue operations are concerns [173, 174].

Due to wide signal availability, a GPS-based indoor positioning system is a very promising tool to provide IPS through the use of repeater [175]. However, GPS does not work accurately in indoor for signal attenuation and interference due to repeater signal with GNSS (Global Navigation Satellite System) signals. Thus smartphone based IPS comes into the scenario because of high cellular coverage and positioning accuracy [176]. In smartphone based IPS, the repeated signal from iBeacon devices is continuously sensed by the BLE devices of smartphones, which is utilized to evaluate the RSSI and update the accurate position. To mitigate the RSSI fluctuations and instability of indoor surroundings problems, a Pedestrian Dead Reckoning (PDR) based indoor positioning technique is developed, which utilizes RSSI with indoor environment map constraints by using particle filters [176].

F. World Wide Interoperability over Microwave Access (WiMAX)

Mobile WiMAX is an upgraded edition of IEEE 802.16 specification (e.g., IEEE 802.16e) that provides scalability, supports network stability, usability assistance, 1.25 to 20 MHz flexible bandwidth as well as stable connections [177]. Due to this, several service providers had used this technology to connect their access points or base stations to the backbone network as a fast and low-cost alternative. WiMAX's principal purpose is to provide easy and low-cost access to remote and challenging field locations for both voice and data communications.

WiMAX is considered the most reliable and energy-efficient system compared to its subsidiary systems like LTE and HSPA+. Thus, WiMAX is widely used for practical purposes because it can serve higher data rates in long-distance communication. Growing demand for the internet in the market and remote areas is fulfilled by using Wi-Fi in conjunction with WiMAX [178].

With advances in the field of wireless systems, hybrid wireless architecture is becoming popular and becomes a part of the scenario for development and deployment in various emergency communication system, for example, the WISECOM project focuses on rapidly deployable lightweight communications infrastructures for emergency situations, where an infrastructure involving a combination of terrestrial mobile networks such as GSM, UMTS, WiMAX and TETRA over satellite are executed. A heterogeneous network consisting with the protocols of IEEE 802.11×and WiMAX network as shown in Fig. 8 is modeled to maintain the same QoS level between the two networks [179].

Smart and supportive telemedicine service such as online healthcare and support for diseases, along with mobile hospitality and ambulance service is the backbone of any health

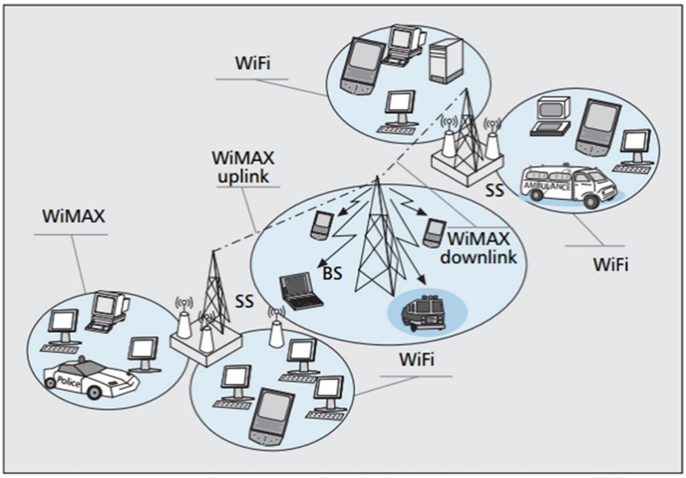

Fig. 8 A heterogeneous WiFi-WiMAX network

system. Such telemedicine services could be a lifesaver in post-disaster situations. An advanced and faster data service is required for telemedicine to tackle patients' high QoS biomedical signals. Thus in [180], the author deliberates a Wi-Max based telemedicine service for city wise health services in Ghana. In [181], the author proposed a WiMAX based rapid emergency network for speedy emergency rescue operation consisting of video surveillance and VoIP service. To assist emergency healthcare with reliable and fast telemedicine service, a practical planning is modeled using blending technology and medical assistance to support users in an emergency [182].

G. Wireless Sensor Network (WSN)

Disaster Management Systems that use wireless sensor Networks (WSN) have received much attention from the researchers. Wireless Sensor Network (WSN) is cheap and reliable and can be deployed in any hostile environments over large geographic areas. The best part of Wireless Sensor Network (WSN) is its auto-configuration and auto organize characteristics [179, 183].

WSN's are suitable to use in disaster scenarios mainly for the two major factors. The first one is the anticipation of a disaster and warning/alert mechanisms and the second one consisting of search and rescue operation perform in the post-disaster scenario with the installation of nodes. Several technology solutions are provided in [184], where authors deliberate the use of WSN for emergency warning and alarm systems to support in search and rescue operations.

A Wireless Sensor Network (WSN) consists of numerous nodes (called Sensors) combined in the form of a network that may be connected to a central node. Wireless Sensor Network (WSN) is deployed in many areas to detect atmospheric humidity, temperature, toxic gases, water level to prevent floods, military monitoring, etc. There are also multimedia sensors to provide real-time photos/videos to the rescuers for getting a better idea about the disaster-affected region. The collection and sharing of information from the area under disaster are other most important features of WSN toward the rescue process [185].

Low energy efficiency and minimal node lifetime is the major limitation of this network. In contrast, the energy efficiency of the network can be improved by compressing the processed data, proper topology control, and choice of appropriate routing protocol etc. It is

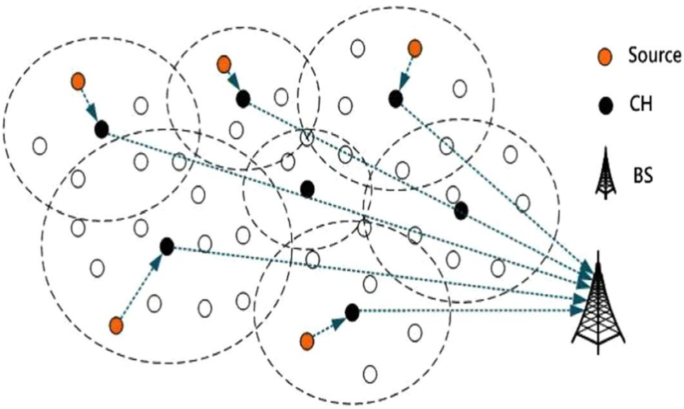

Fig. 9 A cluster-based routing protocol

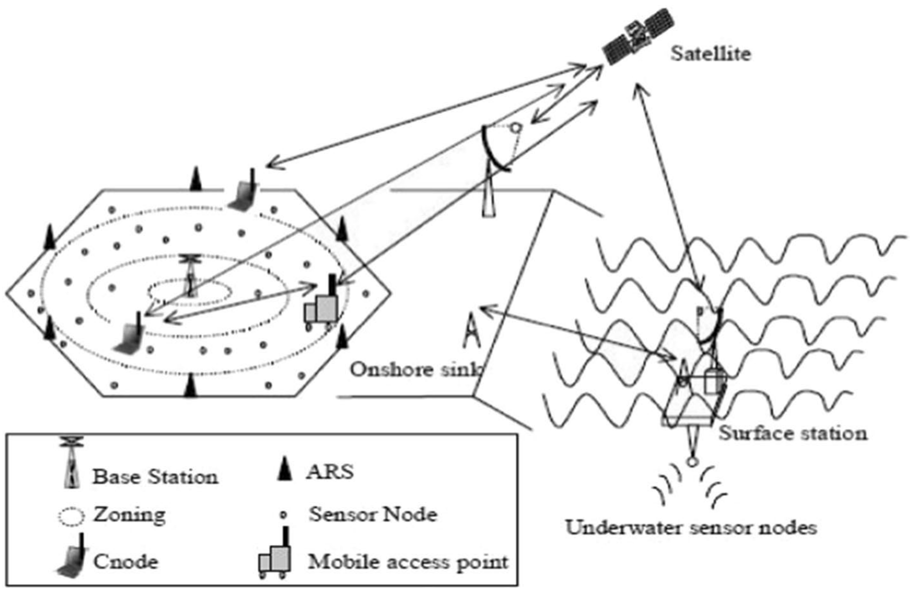

Fig. 10 Under water data collection through WSN

observed that selecting an efficient routing protocol plays a significant role in reducing the energy consumption of nodes.

Figure 9, below shows an idea where authors proposed a cluster-based routing protocol based on WSN architecture. Where cluster head (CH) is selected on the basis of higher power and residual energy of the node. This cluster head receives all the data from the other nodes in the cluster and removes the redundant data, thus the energy consumption is reduced.

Although the cluster head (CH) has higher power and residual energy than the other nodes in the cluster, there is still a need to improve the lifetime of the cluster head, which is a severe challenge. If the base station is at a more significant distance from the cluster head, then deployment of intermediate nodes is beneficial for saving the energy overhead of the cluster head [186]. An Underwater Wireless Sensor Network (UWSN) is used to collect data under the ocean to monitor the possibilities of Tsunami [187].

The Disaster Mitigation is just tracking of disaster. Generally, a tsunami is followed by an earthquake underwater (such as Ocean and Sea). So, if the real-time data of an earthquake underwater is obtained is processed then measures may be taken to evacuate the residents from the disaster-prone areas and thus secure lives and properties.

A tsunami is the result of an underwater earthquake. Thus, if the real-time data of an underwater earthquake is obtained and processed, measures may be taken to evacuate the residents from the disaster-prone areas and secure thousands of lives and valuable properties. One of the proposals is shown in Fig. 10, an Underwater Wireless Sensor Network (UWSN) to collect the data from the earthquake occurring in an underwater environment. Here, an Action and Relay Station (ARS) is located at the border of each cell, and many sensor nodes collectively form a sensor network. The ARS in this stage supports Ad-Hoc Relay and Cellular interface. Using the Ad Hoc Relay interface, one ARS can communicate with other ARS, and using the Cellular interface, the ARS communicates with the base stations of the cellular network. Some circular zones are also initiated to facilitate routing known as zoning. The rescuers also use the Cnode and Mobile access points to collect data from the sensor nodes, and used RFID sensors for tracking the location [188].

Internet of underwater things (IoUT), has the ability to sense location in underwater environment, and also process transmit data in underwater wireless situation. In [189], the author presents the challenges and opportunities in the underwater sensor network for intelligent disaster management and envision future research directions.

A system that uses the WSN and Analytic Network Process (ANP) disaster alert system to predict potential disasters due to landslides is proposed in [190]. In [191], the authors suggest an alert system using WSN for flash floods based on a rural area. For early detection of building fires, a distributed event detection by WSN and assesses machine learning strategies is proposed in [192]. A design of the input sensor interface and the output control interface for a wireless monitoring system for an earthquake disaster is suggested in [192]. Whereas in [193], authors proposed a restricted access window based alert delivery mechanism to improve the reliability and reduce delays in transmitting mission-critical data to the numerous devices in an emergency scenario.

WSN is used to identify wildfires [194], where sensor nodes in a cluster are grouped and configured to track wildfires with temperature and moisture sensors. The obtained information is sent to the control center based on IEEE 802.11 for further estimation. In [195], the authors suggest a multiagent WSN system-based approach for crisis management concerning post-disaster situations. In [196], a novel WSN device is projected, which is named a die-hard sensor network. The system is used for assisting search and rescue instantly in a disaster area.

In [197], an energy efficiency improvement method for WSN is proposed for spatial inquiries on the network, which identify the hazards in disaster situations. The authors of [198] suggest a system that helps victims to send messages from their mobile devices using WSN in disaster areas. A novel routing protocol for better energy efficiency is proposed in [199]. Whereas WSNPDM: a WSN protocol for Disaster Management is introduced in [200] for a better and effective public safety network. In [201], the authors suggest an algorithm for retrieving and storing information on WSNs in post-disaster scenarios to help the rescue team. To improve the delivery of mission critical data, human intelligence is embedded in a wireless sensor network where the network coordinator can detect the critical data and sets an emergency flag at its next beacon to inform the nodes [202].

Constant monitoring and dealing with many casualties in the disaster scenario is a quite difficult task [70]. Localization of sensor nodes and optimal path planning of mobile nodes plays a significant role in disaster communication. A path planning algorithm comprises of localization algorithm with a Mobile Anchor node based on Trilateration (LMAT), and SCAN algorithm (SLMAT) is presented in [203] for efficient disaster management.

In an emergency, proper planning of evacuation can save many lives. A smart evacuation strategy based on simulated annealing by proper balancing the crowd density and movement is proposed in [204], which promises to provide efficient and fast evacuation of people in an emergency. In [205], authors proposed ANT, a deadline-aware adaptive emergency navigation strategy for dynamic hazardous ship evacuation with WSNs, which informs each passenger about a hazard-avoided evacuation path to successfully reach the lifeboats within the specified deadline under all circumstances. ANT also analyses the process of a ship capsizing to predict the specific limited evacuation time and the worst-case traversal delay.

H. Wireless Fidelity—Wi-Fi

Non-infrastructure communication architecture is always preferred to fulfil after disaster communication need, in this regard Wi-Fi could be thought of as an important alternative network for an internet service provider. As the mobile devices available nowadays are all equipped with Wi-Fi hardware to facilitate ad-hoc network with a multihop routing protocol, and sharing its Internet connectivity to the nearby nodes.

Quick, simple, and easy establishment of a connection to the access node is a key requirement for any disaster communication network. Wi-Fi fulfills all the requirements needed in post disaster communication. After a disaster, if there is still few Wi-Fi access point (AP) are alive then small multi-hop network could be possible to establish and connect the zonal user by acting as a master node and provide local communication. If the alive AP has an internet facility, the local disaster-affected user can communicate with the outer zone person for rescue.

As already discussed, the importance of UE energy in disaster communication. So considering the importance of energy in [206], the author proposed an Energy-Aware Disaster Recovery Network using Wi-Fi Tethering (E-DARWIN) architecture, which aid in automatically creating the ad hoc network using smart devices for collection and distribution of data. In [207], the author shows how architecture consists of GPRS with both Wi-Fi and wireless body area network (WBAN) is useful in a disaster. The author discussed the prior necessity of disaster communication's activeness, such as high data rate and low energy consumption with the existing Wi-Fi network.

Wi-Fi is best known for its internet sharing ability during the last decade. Thus researchers are involved in the development of protocol regarding internet sharing through Wi-Fi. In article [208], author investigates the establishment of a WiFi-based multihop access network and discusses how the Wi-Fi provision of the mobile node is utilized for the network setup to share internet connectivity. In [209], author proposed a VAN, where a vehicle is used as an information hub, and the spectrum of TV white space, Wi-Fi, and GSM Network are used according to their availability. Where GMSK modulation scheme was used in four TV band of 1 MHz each in the TV white space with a maximum output power of 10 dBm and through which an average data rate of 900 Kbps was achieved at the distance of 124 m.

To reduce the overhead and manage traffic of the backbone network, WiFi can be utilized. In article [210], the author proposes a solution that uses the concept of Wi-Fi tethering, to manage the traffic in the disaster area.

Through wireless virtualization, the dedicated Wi-Fi NIC card of a device is used for both accessing the internet from the nearest AP and providing internet to the disaster affected victim through creating Wi-Fi hot spot [211, 212]. Virtual Access Point (VAP) is investigated for implementation in a Mobile Node (MN) for extending the coverage of AP. Which proofs the improvement in data rate in DTN network without considering the continuous internet connectivity [212].

Creating a multi-hop access network for public safety in an after-disaster scenario plays a significant role in efficiently providing service to the affected victim [213, 214]. The establishment of virtualizes Wi-Fi network through mobile node elegantly helpful for creating low-cost VAP network [215, 216]. Assuming the affected area has still alive Wi-Fi

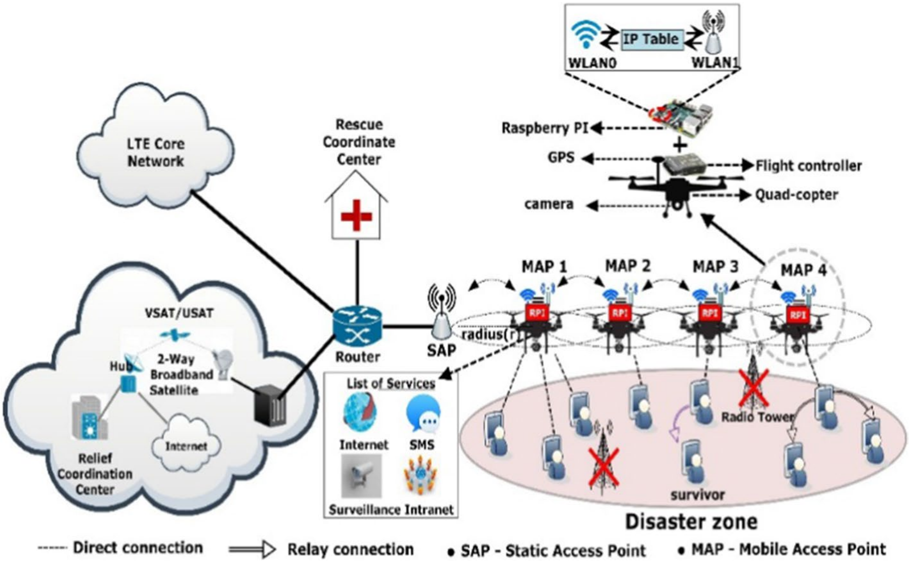

Fig. 11 UAV-aided emergency Wi-Fi Network model for post-disaster management

AP, and the MN of disaster victim get access to the network service from the occasionally created multi-hop network [208].

Deployment of Wi-Fi APs for fast and efficient communication service is always preferred to fulfill all emergency communication requirements and cater to disaster-affected users. In the fast deployment of PS networks, a vehicle-based framework is highly preferred due to less infrastructure and rapid operation [217]. Designing a fast deployable, cost-effective, and resilient emergency network to accelerate search and rescue operation has always been the first motivation for every emergency communication service. In [218], the author discussed the design and implementation of a cost-effective UAV aided emergency Wi-Fi network that will provide onsite surveillance. Furthermore, it provides an extension of existing Wi-Fi coverage using user smartphone and offers helping hand in search and rescue operation (Fig. 11).

The disaster-affected zone is easily cover-up with the deployment of UAVs (Mobile Access Point) to cater the necessary demand of the zone. Thus a cost-effective emergency network is designed with the UAV and Wi-Fi as a static access point [218]. The main aim of the proposal is to provide the necessary communication help and guide saviors to the nearest rescue camp location and pass necessary first-aid tips using a captive android-based portal. Here a mobility model for UAV synchronization is designed and forms a chain network to support on-site surveillance. Where each node is designed as auto reconfigurable to manage connection disruption, and the limited Wi-Fi coverage is extended using existing available resources. The key contribution of the work includes.

- UAV synchronization
- Perform on-site surveillance
- Auto reconfigurable to avoid communication disruption
- Work as helping hand in search and rescue operation
- Extend Wi-Fi coverage using existing smart phones

To help the disaster effected people, there is a need to setup of reliable and robust real time communication system. In [219], author presents a Wi-Fi based real time communication through developing an android application to deliver (a) voice call, (b) text messaging, and (c) tracking the location of affected people. A Wi-Fi based real time communication model is proposed in [220], which promise to provide low latency and highly reliable communication under the framework of heterogeneous network.

4 Probable Disaster MAnagement Solution

The major limitation of all the operated and proposed emergency networks are listed below.

1. *Coverage area limitation* Network/communication node malfunctioning or shut down due to disaster is the most common problem in the During and Post Disaster (DPD) situation, which is a significant challenge in providing seamless connectivity to affected areas. To mitigate such situations antenna height adjustments in base stations is a probable solution. However, it is impractical to have such a provision in all existing setups.
2. *Lack of dedicated Spectrum* In a DPD situation, network congestion is most likely to happen due to the sudden eruption of users' communication requests in the affected and other areas. One of the primary reasons for this is the non-availability of any dedicated spectrum to support such situations. Such a problem is pertinent and prominent in most developing countries like India, where there is no specific spectrum allocated for disaster communication.
3. *Less Reliability* A communication system is reliable if the BS's power supply system is designed to provide an uninterrupted power supply. Installation of lightweight transceiver might be a solution for efficient area power consumption as well as high-speed data and voice communication.
4. *Less Resilience* Resilience of the network is equally essential for emergency communication as network availability in after disaster phase could raise user safety and improve the rescue operation.
5. *Congestion issue* Even though the public safety systems are deployed to work in congestion-free mode, they still get congested during emergencies. Thus, an efficient spectrum management rule needs to be deployed to remove the congestion issue altogether. Therefore, there is a need to investigate the country's entire spectrum distribution and utilize that according to the globally used public safety technology standard.
6. *High implementation time* In a DPD situation, the time needed to implement a PSN is always an important issue. Every single minute is very crucial for the affected human lives in such cases. Setting up an ad-hoc network would take a fair amount of time, leading to a greater loss of human lives. Therefore, there exists a need to develop a pre-deployment model which takes less time to go on-air.
7. *Less user awareness and comfort* Since almost everyone owns mobile phones, it is evident that mobile phones can be an essential part of an effective disaster management system. We are specifically interested in finding out the solutions for disaster communication that will use smartphones.
8. *Less cost-effective* Cost-effectiveness analysis is a form of economic analysis that compares the relative costs and outcomes of two or more courses of action. A fast deployed

PS network able to operate irrespective of telecom operator with the existing network setup could minimize the emergency network's operation cost.

9. *Compatibility with the legacy network* The existing Professional Mobile Radio (PMR) network (like TETRA, TETRAPOL, Project 25, etc.) are not very much compatible with the legacy commercial backbone network. This is a severe problem because the users cannot access the PMR network with their conventional mobile handsets. Thus people won't be able to communicate in an emergency despite having smart devices.

Severe problems which frequently arises and considered as crucial headache of all disaster communication network are listed below.

- Lack of nationwide dedicated spectrum for disaster communication.
- Lack of disaster aware network architecture and post-disaster rescue network [221].
- Un-optimized deployment of communication nodes and data centres [222].
- Un-organized network architecture for data centres [223].
- Unavailability of disaster aware data evacuation and relocation strategy [223].
- Re-designing post disaster communication network based on the availability of resources [224].
- Unavailability of proper electrical power management strategy in emergency network for after disaster phase leading to unorganized rescue operation. To raise the sustainability of the emergency network, author in [225], discussed on the formation of microgrid mechanism to restore critical loads of power after a major natural disaster.

Probable solutions to emergency communications in pre, during (in), and post phase of disaster as listed below.

4.1 Pre-Disaster

- Periodic update of geographical information.
- Periodic inspection of Remote Server connectivity

4.2 In-Disaster

- Initiation of alert message and update through social media

4.3 Post-Disaster

- Fast Response to the Victims.
- Recovery and Reconstruction of Network

4.4 Probable Solution

1. *Optimal Access Point/BS deployment* Optimal deployment of communication node through an efficient optimization algorithm ensures coverage and capacity enhancement of BS.

2. *Development of Energy-aware routing protocol for disaster communication* Efficient energy-aware routing algorithm could minimize the battery-operated node's energy consumption and maximize the lifetime of operation.
3. *Development of Energy-aware Mobile application for disaster relief* Development of a Mobile application for disaster-aware networks could manage the energy consumption of MS while offering a friendly and straightforward user interface.
4. *Efficient Spectrum Management and allocation of dedicated disaster spectrum* The allocation of a nationwide dedicated spectrum for disaster communication could minimize network congestion in the aftermath of a disaster.
5. *Network with Pre-disaster, In-disaster, Post-disaster data evacuation and reallocation optimization* Optimal data evacuation planning could be beneficial for data centre backup. Simultaneously, an optimal route and backup path selection for data centre could enhance the data security.
6. *Disaster Communication Emergency System (ES) Kit pre-install in strategic location and connectivity through satellite* BS with pre-installed ES Kit is proposed to equip with balloon architecture for antenna height increment and has the flexibility to operate in the operator-independent scenario. That ES kit is proposed to design as portable BS and capable to operate in the specific disaster allocated band and in operator-independent scenario. Thus, users of all mobile operators gets an equal chance to access the network during a disaster.
7. *Disaster management through UAV (Unmanned Aerial Vehicle) planning* Development and deployment of UAV for emergency communication enhance the resilience of the network. Furthermore, UAV aided emergency network, enable to work in ad-hoc fashion with the added feature of mobile hotspot and connectivity, and operability as movable flying BS significantly raise the user service at the blackout zone. Design of such UAV aided flying BS could reduce the after disaster communication risk to a certain extend.

5 Conclusions

Recent up-gradation in communication technologies has enormous benefits on the disaster management paradigm. This article provides an overview of the various existing technologies and recent up-gradates in the field of emergency communication technology. Moreover emphasizes the pros and cons of all the public safety standards and the latest research related to public safety aspects of wireless communication. This review also highlights the significant limitations of public safety network architecture and how the recent advances have helped overcome some of those limitations. Finally, the article proposes some probable solutions for the yet unsolved problems related to the emergency communication network. An optimum cell planning of the pre-installed emergency kit based cell, which felicitates adaptive antenna height for large area coverage, will be the most attractive solution for public safety operation in the management of severe large area disasters.

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Declarations

Conflict of interest The authors declare that they have no conflict of interest.

Ethical Approval This article does not contain any studies with human participants or animals performed by any of the authors. This is an observational study. The emergency communication research Ethics Committee has confirmed that no ethical approval is required.

Consent to Participate Informed consent was obtained from all individual participants included in the study.

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