Emergency Satellite Communications: Research and Standardization Activities

Tommaso Pecorella, Luca Simone Ronga, Francesco Chiti, Sara Jayousi, and Laurent Franck

ABSTRACT

Space communications is an ideal candidate to handle critical and emergency situations arising on a regional to global scale, provided there is effective integration among them. The article presents a review of solutions offered by space communication systems for early warning and emergency communication services. It includes an up-to-date review of public research and standardization activity in the field, with a specific focus on mass alert. The main technical issues and challenges are also discussed along with the cutting-edge research from the scientific community.

INTRODUCTION

Climate changes and complex political scenarios have generated unseen contexts for public authorities called to react to emergency situations. Fast chained events require exceptional capacity for monitoring and action, often over wide areas. In the response phase, satellite communication technologies provide operative communications regardless of the availability of regular terrestrial infrastructures. These capabilities are built on three major properties of satellite communications: broadband capabilities with flexible management, inherent broadcasting, and resilience with respect to Earth damage. By taking advantage of these properties in a timely manner, it is possible to effectively apply them to manage the early warning and emergency response phases. With this aim, we present a review of research and standardization activities, specifically focusing on mass alerting. Additionally, we discuss some relevant scientific and technical challenges toward improving the effectiveness of satellite communications.

EARLY WARNING AND EMERGENCY RESPONSE

Satellite communications solutions are deployed at various level of the end-to-end early warning chain. Cosmicheskaya Sistyema Poiska Avariynikh Sudov — Search and Rescue Satellite-Aided Tracking (COSPAS-SARSAT) payloads sent onboard non-geostationary (low Earth orbit SAR, LEOSAR) or geostationary (GEOSAR) satellites are able to detect, locate, and forward emergency signals sent from compliant beacons. LEO satellite constellations, such as Iridium or Globalstar, provide short message services that are used for sending warning messages. For example, the national plan for flood detection and warning in Haiti relies on a combination of general packet radio service (GPRS) and Iridium short burst data message service to send flood detection alerts to a crisis center. Satellite communications can also be used to send warning messages to the actual recipients. In the Haitian flooding warning systems, sirens are triggered through satellites. Finally, satellite backhaul links can be used as backup trunks for critical communications, among them early warning networks.

Early warning systems may benefit from the integration of different heterogeneous space systems. Galileo (Global Navigation Satellite System — GNSS) can provide small data broadcasts to low-cost receivers; real-time sensors over wide areas can be efficiently polled by GEO-based phone systems (i.e., Immarsat, Turaya). A global picture of the evolving context is depicted in Fig. 1. All the main space components (data collection, navigation, interactive data, and broadcast) are here integrated to provide a common early warning system.

When a disaster event strikes, a priority for first responders is to conduct a rapid assessment of the situation and proceed with the initial response missions. Voice and facsimile are favorite bearers of information. Because time is critical, satellite phones and portable satellite terminals, such as the Inmarsat Broadband Global Area Network (BGAN) are the preferred technologies. They are easily available, portable, and provide worldwide voice and limited data capabilities. However, as the operation continues to be rolled out, the intermediate stages of emergency management (e.g., field headquarters) are also deployed with two consequences: the need for long-haul communications shifts from the field to headquarters, and the communications requirements are increased in both volume and services. Satellite very small aperture terminals (VSATs) are then the favorite choice, as they provide broadband capabilities with the capability to backhaul terrestrial traffic coming from professional mobile radio (PMR), cellular, voice over IP (VoIP), and wireless networks.

Tommaso Pecorella, Francesco Chiti, and Sara Jayousi are with Università di Firenze.

Luca Simone Ronga is with CNIT Firenze.

Laurent Franck is with Telecom Bretagne.

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These satellite communication hubs are often located so that the satellite access resources can be shared among the various organizations involved in emergency response.

General Communications Architecture

Although information broadcasting is a natural feature of satellites, the recent growth of machine-to-machine (M2M) data exchange and massive improvements in space-borne radio links have created the basis for new emergency-related services provided by space systems. These features might be advantageously applied to more complex scenarios for supporting critical missions, improving the flexibility, reactivity, robustness, and effectiveness of intervention by means of an efficient and flexible coordination of all the involved nodes. It may be achieved with ad hoc and application-driven networking, complementing the classical telecommunications infrastructure and possibly involving all the potential actors, which are federated in order to accomplish data gathering to achieve context awareness, processing and dissemination tasks, as well as distributed decision making and reconfiguration of the main parameters of the critical mission. In particular, it may involve heterogeneous satellites together with both manned aerial vehicles (MAVs) and unmanned (UAVs). To generalize as much as possible, the architecture consists of a dynamic topology relying on the following nodes, as explained in Fig. 2:

- Heterogeneous satellites.
- Satellite Earth stations (SESs).
- High altitude platforms (HAPs), which are in charge of improving coverage by interconnecting isolated domains. This may be accomplished by directly providing connectivity to ground forces or forming a backbone so that the resulting topology is a mesh, or also involving intermediate nodes acting as relays.
- UAVs, normally in charge of monitoring and sensing a specific region. They can be isolated or act in a group with predetermined instructions.
- MAVs, which make the decisions and intervene on the basis of the fused and processed information.
- A network control center (NCC).

Research Projects and Standardization Activities

A review of public research and standardization activity in Europe is reported in the following sections.

Public Research Activity

The increasing interest in emergency services provided by space is proven by the growing number of research projects addressing this theme. A non-exhaustive list of ongoing or recently concluded projects is provided below.

Alert4All: The Alert4All (Alert for All, EU FP7 2011-2013) project developed an advanced concept for alert and emergency communications from a European perspective. Alert4All investigated five major investigation areas: Authorities and Responders Operations, Human Behavior, Role of New Media, Information Management, and Communications Technologies.

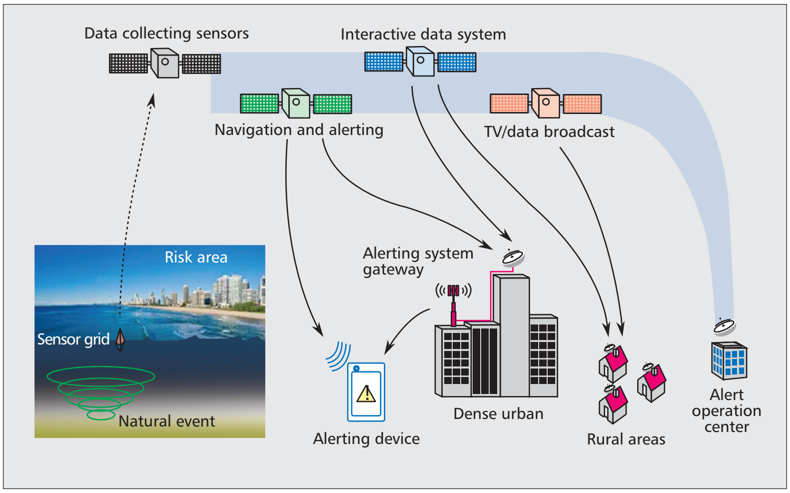

Figure 1. Environmental monitoring and early warning system: architecture overview.

MAIA: The MAIA (Mobile Alert Information system using satellites, EU FP7 2008-2010) project is a feasibility study of a satellite-based system aimed at supporting alert and information dissemination using mobile satellite services in S-band over Europe. The MAIA Alerting System provides one-way messaging from civil protection (CP) agencies to citizens, where terrestrial and satellite-based communications are integrated to enable message reception diversity.

CHORIST: CHORIST (Integrating Communications for Enhanced Environmental Risk Management and Citizens Safety, EU FP6 2006–2009) addressed environmental risk management in relation to natural hazards and industrial accidents. The CHORIST project developed a system composed of three subsystems: a risk assessment report subsystem, a warning message dissemination subsystem, and a rapidly deployable telecommunication subsystem.

MASSCRISCOM: MASSCRISCOM (Mass Crisis Communication with the Public, EU FP7 2009–2011), with the general objective of achieving an increased common capability in society to communicate between competent authorities and the public in crises. Participating partners in the study were mainly emergency agencies from northern European countries. The main component devised in the MASSCRISCOM project was the Crisis Communication Centre (CCC).

ALIVE (ESA): The ESA ALIVE (Alert Interface via EGNOS, 2007–2008) concept is a proposal put forward by ESA to provide emergency communications through a satellite-based augmentation system (SBAS, e.g., EGNOS). ALIVE is conceived to act as an interface between the various disaster management centers and the users (general public) in distress. The purpose is to provide users in distress with useful information about the emerging threat, ways to avoid it, and specific rescue measures to be taken.

MLUTB: The MLUTB (Multi-Constellation

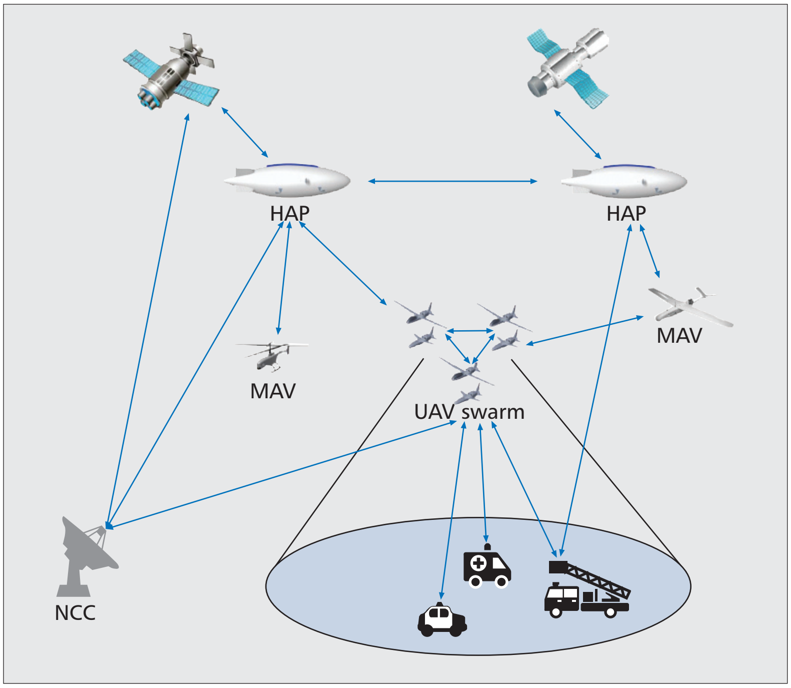

Figure 2. Envisioned integrated communications architecture supporting emergency situations.

Regional System Land Users Testbed, 2010–2011) project is part of ESA's GNSS Evolution program. MLUTB is one of several testbeds intended to support European agencies (ESA and EC), users, and industry in evolving GNSS. The focus of this project is on multi-constellation land users (MLUs), in particular on two different services, the Proof of Position Service (POPS) and Emergency Service (ES).

ABSOLUTE: This project (Aerial Base Station with Opportunistic Links for Unexpected and Temporary Events, EU FP7 2012–ongoing) proposes a rapidly deployable network infrastructure capable of supporting reliable high data rate applications to serve disaster emergency situations. It is obtained through the opportunistic combination of aerial, terrestrial, and satellite communication links with the aim of maximizing network availability, and allowing rapid and incremental network deployment.

EULER: (European Software Defined Radio for Wireless in Joint Security Operations, FP7 2009–2012) aims to define and demonstrate how the benefits of software defined radio (SDR) can enhance interoperability and fast deployment in case of crisis. Considerable effort has been devoted to the definition of SCA-compliant abstraction layers for the integration of heterogeneous components — general-purpose port (GPP), digital signal processor (DSP), and field programmable gate array (FPGA) — for SDR.

WINTSEC: (Wireless Interoperability for Security, Preparatory Activity for Security Research PASR, 2007–2009) is mainly focused on interoperability in public and governmental security (P&GS) systems implementing a "system of systems" approach. WINTSEC explores a mixture of complementary solutions, including SDR, to overcome the barriers for wireless interoperability across different security agencies.

As a general comment, most public research is oriented to the exploitation of available satellite and terrestrial technologies appropriately integrated in a system able to provide a new service. This indeed appears to be the key evolutionary trend in the delivery of emergency applications: no new expensive technologies are strictly required to provide efficient and robust emergency services; instead, a high level of system integration is sufficient. More details on each project can usually be found through the founding institution website (e.g., [1, 2]).

STANDARDIZATION ACTIVITIES

A growing number of standardization actions have been initiated by the main institutions involved. Here some of the most relevant bodies and documents in the European context are summarized.

ETSI SES-SatEC: The Satellite for Emergency Communications (SatEC) working group is probably the most focused on satellite applications. Part of the European Telecommunications Standards Institute (ETSI) Satellite Earth Stations (SES), it produced a set of documents related to various aspects of satellite assisted emergency communication services. TR-103-166, "SatEC; Emergency Communication Cell over Satellite," outlines the concept of emergency communication cells over satellite (ECCS). An ECCS is understood as a temporary emergency communication cell supporting terrestrial wireless and wired standards (based on IEEE 802.11, dPMR, IEEE 802.16, 3GPP LTE, or ETSI TETRA), which are linked/backhauled to a permanent infrastructure by means of bidirectional satellite links. The document, besides describing ECCS architectures based on existing products, introduces the challenges in providing interoperable services, and gives an overview of commercial available products and ECCS solutions. TS-103-284 [3] presents a formal classification of ECCS devices taking into account communication, mobility, and energy consumption capabilities, together with robustness and physical features.

TR-102-641, "SatEC; Overview of Present Satellite Emergency Communications Resources," presents an overview of concepts, systems, and initiatives related to the use of space resources in the context of disaster management. The SatEC working group also promoted two EU-funded specific task forces (STFs) devoted to the production of standardization documents in this field. In particular, STF472 is devoted to the definition of reference emergency scenarios, while STF473 will define MAMES, a multi-protocol alert message encapsulation (see below).

ETSI EMTEL: Although not strictly related to satellites, the Emergency Communications (EMTEL) group addresses a broad spectrum of aspects related to the use of telecom services in emergency situations. TR-102-180/182 define the requirements for communication during emergencies among the various entities (citizens, authorities, individuals). TR-102-144 considers the use of short message service (SMS) and cell broadcast service (CBS) for emergency applications, while TR-102-476 presents some solutions for the adoption of VoIP during crises.

IETF ECRIT: The Internet Engineering Task Force (IETF) Emergency Context Resolution with Internet Technologies (ECRIT) initiative, collects several aspects related to the use of Internet services during emergencies. Among them we can mention RFC 5012, "Requirements for Emergency Context Resolution with Internet Technologies", where the baseline requirements are investigated; RFC 5031, "A Uniform Resource Name (URN) for Emergency," leading to a standard resource naming for emergencies; RFC 5069, "Security Threats and Requirements for Emergency Call Marking and Mapping," investigating on VoIP security aspects; RFC 5222, "LoST: A Location-to-Service Translation Protocol," where a context-aware service access mechanism is formulated; RFC 5582, "Location-to-URL Mapping Architecture and Framework," for location aware naming; and RFC 6443, "Framework for Emergency Calling Using Internet Multimedia," where the adoption of multimedia streaming for emergencies is considered.

EMERGENCY INFORMATION DISSEMINATION: SYSTEMS AND PROTOCOLS

One of the key requirements for efficient delivery of emergency information (communication from authorities to citizens) is to quickly reach the highest number of people within the affected areas coping with critical operation conditions. Taking into account a common notification service for all types of emergency, [4] reports a collection of operational, organizational, and technical requirements, providing a comparison of the main communication technologies adopted for the dissemination of emergency notifications. Focusing on satellite technologies, the summary below includes an overview of the capabilities of SATCOM/SATNAV systems, highlighting their compliance/non-compliance with some of the main requirements identified in [4] and taken as a reference for the purpose of this article.

EXAMPLES OF EXISTING ALERTING SYSTEMS

Existing alerting techniques rely on basic traditional methods (e.g., loudspeakers, sirens, public displays), broadcast transmission (e.g., paging, radio, and TV broadcast), and personal interactive communications devices (e.g., terrestrial and satellite mobile networks, web/social media), ranging from small local footprint to continental or global reach. However, the use of satellite networks, despite their resilience against terrestrial damage, are currently used mostly for niche applications. Two examples of dedicated alerting systems that use satellite broadcast as dissemination technology for emergency information delivery are the Satellite-Based Warning System (SatWaS) and Modular Warning System (MoWaS).

SatWaS is a German alerting system developed by the Bundesamt für Bevlkerungsschutz und Katastrophenhilfe (BBK) (Federal Civil Protection Agency) to disseminate via satellite urgent alert information in case of major national security incidents or threats. This system is gradually replacing sirens in Germany. However, it does not aim to directly alert the population; in fact, the SatWaS warnings are sent to regional situation centers, public/private media broadcasters, Internet providers, paging services, and press agencies, which in turn are in charge of forwarding the alert messages to the general population.

MoWaS is a modular upgrade of SatWaS, which is currently being developed with the objective of allowing local civil protection authorities to activate all alarm and warning systems in their area of responsibility in a decentralized manner and without discontinuity of media use. Unlike SatWas, MoWaS warnings can directly reach the population via any connected means, and in order to disseminate alerts CBS and Terrestrial Trunked Radio (TETRA) are introduced as communication technologies.

SATCOM/SATNAV SYSTEMS FOR EMERGENCY INFORMATION DELIVERY

The adoption of satellite technology for distributing alert messages allows reliable warning of the population and the authorities about a hazard. From the point of view of the deployment of an efficient alert network, the following categories of satellite systems can be considered: broadcast fixed/mobile satellite system (without return link) and bidirectional fixed/mobile satellite systems. The adoption of the first class of the satellite systems (e.g., DVB-S2, DVB-SH based) enables the alert messages to broadcast over a large area, reaching both home users with traditional satellite TV receivers or additional temporary communication terminals installed for emergency purposes and mobile users equipped with satellite radio and multimedia receivers. On the other hand, the bidirectional feature of the second class of systems and, in particular, the intrinsic robustness of satellite two-way systems allow alert message transmission to users equipped with VSAT terminals and to mobile users with satellite mobile devices subscribed to one of the data services provided by Inmarsat, Thuraya, Globalstar, and Iridium. The bidirectional systems allow the transmission of acknowledgment of the delivery success of the alert message (an optional feature useful mainly for authority-to-authority communications). Among the existing systems, it is worth mentioning Iridium Short Burst Data Service, which is particularly suitable for a global alert message distribution network.

Besides the traditional SATCOM systems, the use of the available data channels of SATNAV systems, such as SBAS and GNSS (e.g., Galileo), has recently been investigated for the provision of alert messages. Combining the mass diffusion of mobile location-aware receiving devices and the location information provided by a SATNAV system, alert messages can be transmitted over a large area or a specific target area, and at the user level the receiving

Combining the mass diffusion of mobile location-aware receiving devices and the location information provided by a SATNAV system, alert messages can be transmitted over a large area or a specific target area and at user level the receiving device could be able to determine based on its current location, whether or not that particular message is relevant to it.

At the physical layer, the exploration of higher frequency bands (W band 80–90GHz) will allow the creation of precise shaped and compact multi-spot antennas increasing dramatically the throughput per unit area. New antenna technologies like meta-materials will also support this trend.

	SATCOM				SATNAV
Requirement	**Broadcast fixed**	**Broadcast mobile**	**Bidirectional fixed**	**Bidirectional mobile**	**GNSS**
Mass distribution of alerts	✓	✓	*	*	✓
Reach mobile users	–	✓	–	✓	✓
Adequate capacity (data rates)	✓	✓	†	†	‡
Alert delivery acknowledgment	–	–	✓	✓	–
Legend	✓ = compliant – = non-compliant * = potentially suitable, mainly designed for point-to-point communications † = medium/low data rate ‡ = very low data rate				

Table 1. Satellite systems comparison: SATCOM/SATNAV systems vs. requirements.

device could be able to determine, based on its current location, whether or not that particular message is relevant to it. Although SATNAV systems can be used for alerting purposes, some of their main limitations need to be taken into account in the design of an alert message protocol (available bandwidth, time to alert, etc.). Focusing on the Galileo system, both commercial service (CS) and public regulated services (PRS) could be considered as two main candidates for the delivery of alerts. The former mainly targets the market of commercial applications, and thus can be used for the transmission of alert messages to the population. While the latter is particularly suitable for sensitive applications, since it is restricted to government-authorized users, it can be used for the delivering of alert messages to public protection and disaster relief (PPDR).

Message Format for Exchanging Emergency Alerts

Among existing formats for exchanging alert messages, Common Alerting Protocol (CAP) is currently the international de facto standard for alert messages. It is developed by the Organization for the Advancement of Structured Information Standards) and adopted by the International Telecommunication Union (ITU) as X.1303. CAP is part of the Emergency Data Exchange Language (EDXL) family, which is a suite of XML-based messaging standards aimed at improving emergency information sharing among emergency management entities. It is a simple but general format for exchanging emergency alerts and warnings over different networks. CAP allows all kinds of alerting and public warning systems to be activated, ensuring information consistency over multiple delivery systems and increasing emergency management effectiveness. While a CAP message can also be used to acknowledge reception of an earlier CAP message, the CAP specification does not support or mention any compression schemes. Therefore a typical human-readable XML-based CAP Alert Message has a size of about 1.5 kB, which can be reduced to 1 kB using zip compression. To cope with this issue, which may exclude the transmission of CAP messages over narrowband channels, an efficient compression scheme for XML-based CAP messages was defined in the framework of the Alert4All project as better described in the following subsection.

Alert Message Transmission Protocols

This section gives an overview of the existing initiatives for alert message protocol definition, focusing on a project-driven solution (A4A protocol) and the ongoing ETSI standardization activity within SES/SatEC (Specialist Task Force STF473) for the encapsulation of alert messages (MAMES — Multiple Alert Messages Encapsulation over Satellite). However, for completeness, the following past standardization activities are mentioned: Lightweight Emergency Alerting Protocol (LEAP) and Encoding Secure Common Alert Protocol Entities (ESCAPE), produced by the IETF Authority-to-Citizen Alert (ATOCA) Working Group (whose work concluded in November 2012), and the Post Office Code Standardization Advisory Group (POCSAG), currently used in many countries to distribute urgent information, including emergency and alarm communications.

A4A protocol — Aiming at the transmission of alert messages within size-limited frames of GNSS (e.g., GPS, EGNOS, Galileo) systems (possibly avoiding fragmentation), the A4A protocol consists of processing and translating CAP messages [5]. In detail, only the mandatory fields of a CAP message are encoded into specific protocol header fields. A modular structure of the message allows the definition of new functional blocks according to system requirements, resulting in a flexible protocol toward extensions. Moreover, for an efficient encoding and compression scheme, the use of an alert library structure was considered, and additional functionalities are implemented for fragmentation, priority management, source authentication, security mechanisms (encryption, message integrity), and robustness against link errors.

MAMES Protocol — The main objective of the MAMES protocol comes from the need to transport alert messages over satellite links for fast distribution of an alert to the population [6]. Specifically, MAMES aims to define a flexible encapsulation scheme for carrying diverse alert messages over different satellite communication technologies, which include the Galileo system (CS and PRS services). To cope with the heterogeneity of the alerting devices, which may need to be activated simultaneously, MAMES investigates the possibility of supporting the transmission of multiple concatenated alert messages, formatted according to different alert protocols. Moreover security mechanisms and the optional use of acknowledgments are considered for authority-to-authority communications. To provide a protocol flexible to extensions and enable transmission over narrowband channels such as the GNSS systems, the MAMES message structure is inspired by the packet data unit (PDU) structure of IPv6 (next header concept), where the header consists of a primary header followed by extension blocks. This allows the definition of MAMES mandatory and optional functions related to the message encapsulation and ancillary functionalities, respectively.

Summary: Satellite System and Protocol Comparisons

A comparison among the different classes of satellite systems, which may be adopted for alert messages delivery, is reported in Table 1, which shows the capabilities of each system in terms of compliance or non-compliance with some of the key requirements of an emergency notification service. It is worth highlighting that among the listed requirements, compliance with *mass distribution of alerts* and *adequate capacity* allows the simultaneous distribution of alerts in a short predictable period of time to the targeted large areas (and intended audience). Moreover, the highlighted limited bandwidth capacity of SATNAV systems requires the development of efficient protocols opportunely designed to cope with such a constraint. On the other hand, an overview of the previously described protocols for alert dissemination is provided in Table 2, where CAP, A4A, and MAMES are compared in order to highlight their benefits and limitations.

Scientific Challenges

Recently, research on emergency communication scenarios is mainly focused on system interoperability, higher frequency band utilization, transmission efficiency, and fast system reconfiguration.

Concerning system interoperability, it may be achieved using different approaches, such as satellite-independent service access points (SI-SAP [7]). Moreover, it is generally assumed that IP represents an unifying technology.

Key feature	CAP	A4A	MAMES
Alert message format	Yes	No	No
Encapsulation protocol	No	Only CAP	Multiple (concatenated) alert messages
Encoding scheme	No	Only for CAP	No
Tx over SAT narrowband channels	Out of scope	Efficient CAP encoding	Within the scope

Table 2. Protocol comparison: CAP vs. A4A vs. MAMES.

At the physical layer, the exploration of higher frequency bands (W band, 80–90 GHz) will allow the creation of precisely shaped and compact multi-spot antennas, dramatically increasing the throughput per unit area. New antenna technologies like meta-materials will also support this trend.

Another relevant challenge in satellite communications is the improvement of the transmission efficiency. Satellite networks are high delay-bandwidth product networks. The network delay cannot be reduced below a physical limit depending on the satellite orbit, and the jitter caused by packet retransmissions can negatively affect communications performance. In order to enhance protocol performance, several techniques have been proposed, ranging from predictive bandwidth allocation [8] to the use of network coding (NC) principles [9].

NC can be useful in several satellite communication scenarios; for example, when a satellite multicasts a flow to a selected set of receivers, a receiver may decode information from more than *one* satellite, or satellite *trunking* services.

NC was introduced a decade ago in [10] to improve network capacity. It consists of combining several packets using random coefficients in a finite Galois field. It can be done at the physical layer (physical NC, PNC) or at higher layers (digital NC, DNC). As a matter of fact, NC represents a bandwidth-efficient (spectrum and energy efficiency) technique for wireless multicast broadcast services (MBSs) in comparison to traditional automatic repeat request (ARQ) or hybrid ARQ (HARQ) protocols [11].

NC may improve transmission efficiency and reduce delay, even though its optimization is a typical NP-hard problem. Consequently, it requires the development of specific heuristics in order to reduce the number of packet (re)transmissions.

Moreover, NC can be used for strict delay-constrained contents. In this case it is useful to resort to block-based transmission schemes such as random linear network coding (RLNC) [12]. It is worth mentioning that the goal may be to maximize the packet delivery ratio or, alternatively, minimize the block *completion* time for a set of users [13].

Another interesting application field is represented by satellite *relay* networks, where relays may have to provide connectivity to multiple sources. In this case, a promising approach

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encourages users to interfere and exploit the interfered signals to increase the network capacity. This can be achieved by using PNC [14], which could potentially double the capacity of two-way relay networks in both synchronous or asynchronous scenarios.

PNC can be effectively used in conjunction with spatial diversity (SD) techniques in order to overcome losses in wireless fading channels, particularly for relay scenarios where multiple sources cooperate and communicate with a single destination through a relay. This represents the typical case of uplink satellite systems, where this approach could reduce the probability that the receiver is unable to collect all the information packets sent by the source [15].

At the IP level, multiple techniques have been proposed to increase the satellite network efficiency. Protocol compression (e.g., ROHC, RFC 5795) may be used, but the system scalability for sporadic connections must be evaluated. The transport layer, and in particular TCP, has been extensively studied. The proposed approaches are to rely on specific TCP flavors (e.g., TCP Hybla, TCP Noordwijk) or use TCP proxies (PEP — Performance Enhancing Proxy, RFC 3135). The two approaches are complementary: satellite-specific TCP (or even specific transport layers, e.g., SCTP) have better scalability, but they are limited to cases where the terminals are aware of the satellite network segment. If the endpoints cannot dynamically adjust the TCP flavor, PEPs are an interesting alternative.

Recent advances in reconfigurable signal processing devices also open the door to software defined radio technology in space. Hybrid computing architectures based on field programmable gate arrays, where radiation hardened and redundant schemes are jointly employed to provide a space tolerant functional blocks, allow the adoption of software configuration capabilities for payloads. The advantages are enormous in terms of flexibility and efficiency of the spacecraft that can evolve through its usually long lifetime.

Conclusions

Environmental changes are leading to ever more frequent natural events with regional (sometimes global) impact on peoples' lives. Space communications have great potential to help in emergency management, even though this potential is still not fully exploited due to limited or even nonexistent integration among different satellite systems. Two main contributions can be provided by satellite systems to the management of crises: dramatic reduction of latency in the delivery of alerts to the population, and efficient and robust exchange of information among emergency operators and authorities. Several ongoing activities have been reported, essentially conducted through research projects and standardization activities. The emergency context also represents a great research opportunity for scientists, whose aim is the improvement of quality, efficiency, and availability of emergency communications assisted by satellites.

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Biographies

Tommaso Pecorella [S'90, M'00] received his Dr.Ing. degree in electronics engineering from the University of Firenze, Italy, in 1996, and his Ph.D. degree in telecommunications engineering in 1999. In 2000 he joined CNIT, the Italian University Consortium for Telecommunications, as a scientific researcher. Since 2001 he has been an assistant professor at the University of Firenze. His research interests involve computer communications, mobile communication networks, QoS-enabled access schemes, satellite communication networks, queuing theory, wireless sensor networks, ad hoc routing, network simulations, network management, and security.

Luca Simone Ronga (luca.ronga@cnit.it) [S'89, M'94, SM'04] received his M.S. degree in electronic engineering in 1994 and his Ph.D. degree in telecommunications in 1998 from the University of Florence, Italy. In 1997 joined the International Computer Science Institute of Berkeley, California, as a visiting scientist. In 1999 he joined CNIT, where he is currently head of the research area. He has been Editor of the *EURASIP Newsletter* for four years, a member of the ETSI SatEC working group, and a member of NATO Task Force on Cognitive Radio. His research interests span from satellite communications to cognitive radio, software defined radio, radio resource management, and wireless security. He has been principal investigator in several research projects and AN author of more than 90 papers in international journals and conference proceedings.

FRANCESCO CHITI [M'01, S'13] received his Ph.D. degrees in informatics and telecommunications engineering from the University of Florence in 2004, where he is presently working as an associate professor. His current research topics are devoted to link and network layer protocol design for ad hoc and sensor networks. He has taken part in several European research projects, such as REGPOT AgroSense, IP GoodFood, STREP DustBot, NoEs NEWCOM and CRUISE, GJU TWIST, ETSI STF179, and COST 289 action. He serves as Associate Editor of the *Wiley International Journal on Security and Communication Networks*. He is an author of three book chapters, more than 20 journal papers, and more than 50 conference papers.

SARA JAYOUSI received her Ph.D. degree in computer science, multimedia, and telecommunications in 2012 from the University of Florence. She has been with the Department of Information Engineering of the University of Florence since 2008. Her research activity is mainly focused on satellite communications for emergency, IP QoS network management in hybrid satellite/terrestrial networks, cooperative communications, and diversity algorithms in relaying systems. She is an author of several transactions and conference papers.

LAURENT FRANCK [SM] graduated in computer science (1994) and social sciences (1998) from Brussels University. In 2001, he received a Ph.D. degree in telecommunications from Télécom ParisTech and an Habilitation à Diriger des Recherches from the Institut National Polytechnique de Toulouse in 2009. Since 2007 he has been with Télécom Bretagne (Toulouse site) where he teaches and conducts research on satellite communications. His main research interest lies in the development of satellite-based emergency communications. Laurent is involved in ETSI standardization activities. He has also been a first aid worker and team trainer with the French Red Cross for 14 years.