

Interworking between MANET and satellite systems for emergency applications

Michele Luglio^{1,*†}, Cristiano Monti², Cesare Roseti¹, Antonio Saitto²
and Michael Segal³

¹ *Department of Electronics Engineering of University of Rome 'Tor Vergata', Rome 00133, Italy*

² *Telespazio, Rome 00156, Italy*

³ *Ben-Gurion University of the Negev, Beer-Sheva, Israel*

SUMMARY

This paper presents the main achievements of a project, focused on the design of an integrated system composed of a satellite segment and a MANET to provide telecommunication services in emergency scenarios, in terms of network design, focusing in particular on the development of the interface between the two systems and showing the results of field trials. Copyright © 2007 John Wiley & Sons, Ltd.

Accepted 23 June 2007

KEY WORDS: MANET; emergency; satellite; interoperability

1. INTRODUCTION

During emergency events, operators working in difficult and complex environments primarily require both voice and data services (including pictures and moving images).

MANET (Mobile *ad hoc* Networks) and satellite technologies are complementary because MANETs are characterized by very small, low-power consumption, limited capacity terminals and work in a very limited coverage range, while satellite systems work with medium/large dimension, medium/high-power user terminals and cover very wide areas. Moreover, MANETs are very suitable to work also in indoor environments where signals from satellite systems usually do not penetrate.

*Correspondence to: Michele Luglio, Department of Electronics Engineering of University of Rome 'Tor Vergata', Rome 00133, Italy.

†E-mail: luglio@uniroma2.it

Contract/grant sponsor: Italian Ministry of Foreign Affairs

Contract/grant sponsor: Ministry of Industry of Israel

User requirements can be satisfied guaranteeing two features [1]:

- Interconnectivity among team members and among different teams involved in the emergency activity achieved without using additional frequency bands, both for existing radios and for the new generation ones,
- Interconnectivity between teams in the field and remote users (typically high and medium level managers not present in the emergency area).

Due to the combined use of ‘*ad hoc* networks’ for local connectivity and easy deployable satellite stations for remote connectivity, the network configuration satisfies the typical needs of emergency communications: easy transportability and setting up, low weight and power consumption, limited maintenance and basic network centric operation functionality.

However, many *ad hoc* networks recently designed and proposed have two major drawbacks which limit their use for emergency rescue teams: the first is the difficulty of using a data network for voice, the second is the low efficiency of the connectivity protocols, mostly due to IP architecture, not optimized for the radio communication channel. In addition, the link to the remote center may be unreliable due to channel conditions or to not full compatibility between protocols of different networks.

To improve on this, the system presented in this paper consists of a cost-effective solution to create a module based on two basic features:

- A new ‘*ad hoc* network’ architecture that uses a protocol optimized for voice (peer to peer and common channel) and allowing data and image communications *via* self-configured relay terminals to overcome the lack of line of sight.
- A simple interface with narrowband or broadband satellite terminals.

2. REFERENCE SCENARIO

On the basis of the requirements of fire fighters of Trento (Italy), and assuming that the users are uniformly distributed in a bi-dimensional plane, three different ranges of distances have been considered:

- R1 (outdoor areas without obstacles), maximum single-hop distance ~ 500 m,
- R2 (outdoor areas with only a few obstacles), maximum distance ~ 300 m,
- R3 (indoor areas with many obstacles), maximum distance ~ 50 m.

In the identified scenario a team or several teams, each composed of a dozen of units, are deployed in a potentially wide area. We refer to the scenarios where a certain number of teams, belonging to the same command or independently coordinated (i.e. military forces, police, fire fighters, rescue teams, etc.), cooperate in the same mission and have the following requirements in terms of connectivity: between units of the same team, between units belonging to different teams using different systems or technology or equipment, with a remote station. Such objectives are achieved through a wireless *ad hoc* network with access to satellite communication networks at a very low cost and high reliability [2] (Figure 1 shows the conceptual architecture while Figure 2 shows the test-bed configuration).

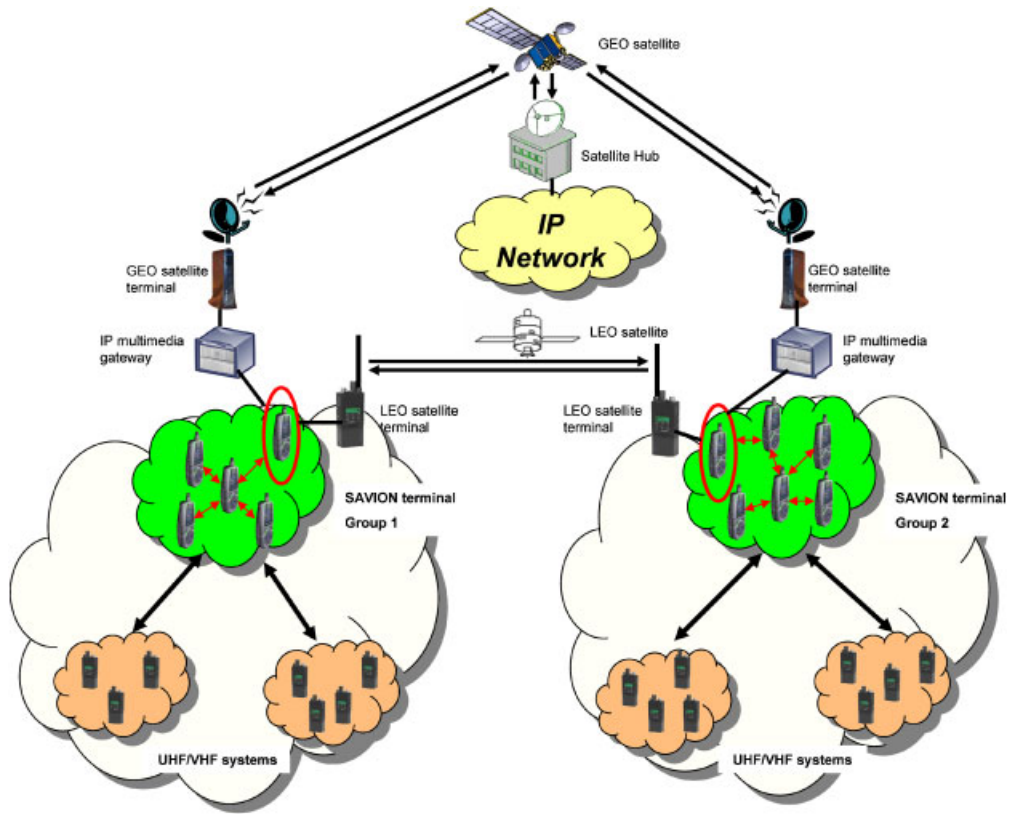


Figure 1. Reference scenario.

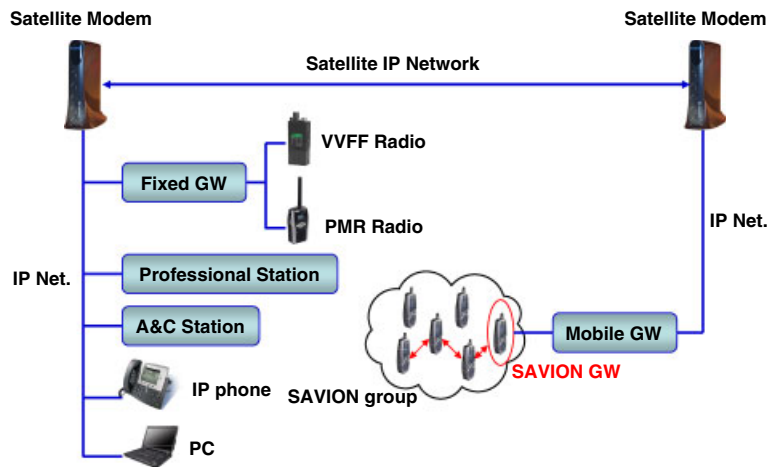


Figure 2. Test-bed configuration.

3. THE SAVION DYNAMIC MESH NETWORK

Mobile unit works in the 2.4-GHz band and the modulation technique used are spread spectrum. It uses a standard short-distance transceiver with an advanced algorithm and voice compression system. The system is capable of receiving and transmitting data and voice up to 1.6 km using no more than 10 hops. Due to the system mesh networking capabilities, it operates in very harsh environments and conditions where regular radio transmission fails. Parallel and simultaneous voice and data communications are also allowed. The nodes movements result in local updates of node table that are carried out in constant time. The mobile unit survives up to 100 users, uniformly spread over 2 km² (outdoor), all using the same frequency, allowing extreme bandwidth efficiency. Both data (asynchronous) and voice (synchronous) communications with a total bandwidth of 1 Mbit/s are supported. The unit can work as stand-alone with voice and data capabilities or be connected to another device. The Generic Radio Control unit allows remote access of the network and parameters selection.

Two typical operation modes can occur: Unit Network Discovery or Request of Transmission. In the former case after a group of units have been activated, the network takes at most 5 s to be ready for any type of communication. In the latter case any transmission request will be forwarded with a Push-to-Talk mode (for voice) and data user interface (for data) implying a communication activation request. This request will command the network to create a communication path for the connection type requested (like Broadcast, P2P, grouping, etc). The network will handle and serve more than one voice/data request simultaneously.

4. MANET–SATELLITE INTERCONNECTION

Three different communication segments are involved in the SAVION system:

- A MANET.
- A satellite segment that in turn can be assumed as narrowband segment or broadband.
- A MANET–satellite interface.

The system can be configured depending on both the operational needs and the requested services. To build up interconnection between the *ad hoc* terminal, set as gateway, and the satellite terminal two satellite solutions have been identified: Globalstar (Telit SAT 600 terminal) and a Ku-band satellite of the Eutelsat fleet (e-bird 33° East) with the ground segment from Hughes Network Systems (DW7000 terminal).

4.1. Interface MANET–narrowband satellite system

The TELIT SAT 600 mobile phone (Figure 3) can be directly connected to the SAVION gateway unit through the data transmission module DT 600 included in the Telit data kit pack [3]. Such a module allows the SAVION gateway unit to use TELIT SAT 600 as an external modem by installing an appropriate driver.

4.2. Interface MANET–broadband satellite system

The conversion of both the analogue voice signal and digital data, coming from the SAVION gateway unit, into IP datagrams to forward to the IP broadband satellite terminal



Figure 3. MANET-Globalstar connection.

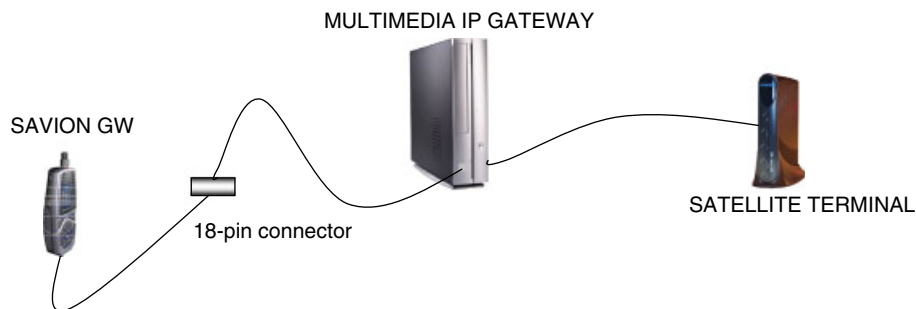


Figure 4. MANET-VSAT interconnection.

is performed through an IP multimedia gateway able to interface radio systems to IP networks (Figure 4).

5. ACHIEVEMENTS

The tests have been oriented to highlight the properties of the *ad hoc* mesh network and to demonstrate the interconnection to the satellite segment, both through a broadband modem and a narrowband terminal. The last set of trials was performed at Telespazio premises.

5.1. *Ad hoc mesh network tests*

A set of tests has involved six SAVION terminals (Figure 5) to provide simultaneously private calls, group calls, broadcast calls, and data transfers. The tests were performed in different environments: indoor environment (fire fighter's base and exhibition pavilion), tunnels, outdoor. Table I summarizes the results for both voice and data applications.

5.2. *Voice service through broadband satellite terminal*

The architecture of the test bed is shown in Figure 2. Each SAVION terminal belonging to a group has been connected (for both voice and data communication) *via* a satellite IP network to the following remote systems/terminals: fire fighter's radio (VVFF radio),

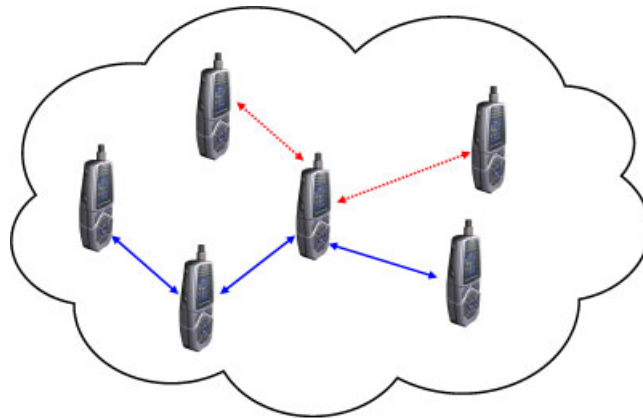
Figure 5. *Ad hoc* mesh network.

Table I. Trial achievements.

Test id	Single-hop distance (m)	Overall coverage (m ²)
Indoor (base)	~ 10	~ 200
Indoor (pavilion)	~ 200	~ 8000
Tunnel	~ 200	—
Outdoor	~ 320	—

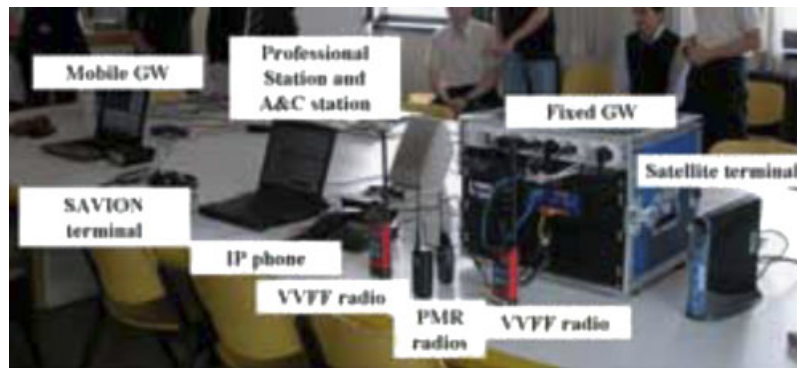


Figure 6. Test bed in Trento.

a generic private mobile radio (PMR radio), an IP phone, a PC. As far as the interface elements is concerned:

- The Fixed GW is a station used to interconnect the VHF radio to the IP satellite modem,
- The Mobile GW is a station used to interconnect the SAVION GW to the IP satellite modem (through an USB interface),

- The Professional Station manages the communications,
- The A & C Station is the control center that manages and controls all the tasks performed in the fixed/mobile GW.

Figure 6 shows the picture of the test bed deployed in Trento.

5.3. Data transfers through Globalstar terminal

The test bed included two Telit DT600 terminals connected to two PCs, running Windows XP operating system, through a RS232-USB adapter. Both a data channel (non-TCP/IP) and a TCP/IP connection have been successfully set up and used for chatting and file transfers.

6. CONCLUSION

This paper presents the characteristics of the SAVION network designed for emergency communication. In particular, it concerns the definition and the implementation of an integrated satellite-*ad hoc* network architecture.

ACKNOWLEDGEMENTS

The work performed in the SAVION project was funded by the Italian Ministry of Foreign Affairs in cooperation with the Ministry of Industry of Israel. Thanks to the volunteer Fire Brigades of Trento for their irreplaceable support and hospitality.

REFERENCES

1. Luglio M, Monti C, Saitto A, Segal M. Interfacing satellite systems and ad hoc networks for emergency applications. *Third Advanced Satellite Mobile Systems Conference*, Herrsching am Ammersee, Germany, 29–31 May 2006; 396–401.
2. Luglio M, Nicolai G, Splendorini L, Vatalaro F, Zuliani L. Combined use of Italsat and Globalstar for monitoring and disaster recovery purposes. *Seventh Ka Band Utilization Conference*, Santa Margherita Ligure, Italy, 26–28 September 2001; 77–84.
3. <http://www.elsacom.it>

AUTHORS' BIOGRAPHIES

Michele Luglio received the Laurea degree in Electronic Engineering at University of Rome 'Tor Vergata'. He received the PhD degree in telecommunications in 1994. From August to December 1992 he worked, as visiting Staff Engineering at Microwave Technology and Systems Division of Comsat Laboratories (Clarksburg, Maryland, USA). From 1995 to 2004 he was research and teaching assistant at University of Rome 'Tor Vergata'. At present he is associate professor of telecommunication at the same university. He works on designing satellite systems for multimedia services both mobile and fixed. In 2001 and 2002 he was visiting Professor at the Computer Science department of University of California Los Angeles (UCLA) to teach Satellite Networks class. He taught Signal Theory and collaborated in teaching Digital Signal Processing and Elements of Telecommunications. Now he teaches Satellite Telecommunications and Signals and Transmission.

Cristiano Monti received the Electrical Engineering degree, the MBA and the PhD degree in Telecommunications and Microelectronic Engineering, in 2000, 2002, and 2007, respectively, all from the University of Rome Tor Vergata, Rome, Italy. Since 2001 he was involved in several national TLC research projects. His main research interests include analysis of interoperability, security and coexistence issues on wireless and Satellites systems. Since 2006, he's involved in research projects regarding safety and security issues for Innovation Department of Telespazio. He's author of many papers for international reviews.

Cesare Roseti graduated cum laude in 2003 in Electronic Engineering at University of Rome 'Tor Vergata'. In 2003 and 2004 he was a visiting student at Computer Science Department of University of California, Los Angeles (UCLA). From August to December 2005 he worked at the TEC-SWS division of the European Space Agency (Noordwijk, The Netherlands). He received the PhD degree in 'Space systems and technologies' in 2007. Collaborator in the 'Satellite Telecommunications' class at the University of Rome 'Tor Vergata' His research interests include satellites communications and protocol design, cross-layer interactions, implementation and performance analysis in wired/wireless networks.

Antonio Saitto received the master degree in Electronic Engineering at the University of Rome 'La Sapienza'. He was at Selenia as Antenna System Designer from 1972 to 1980, at European Space Agency (Noordwijk, Holland) as Senior Scientist between 1980 and 1983, Ground Segment Division Technical Director at Alenia Spazio from 1985 and 1992, at Alenia-Marconi Communications (Pomezia) as Technical Director between 1993 and 1995, at Marconi Services as Marketing Director of Southern Europe from 2001 to 2003. At present he is responsible for the Innovation Strategy and Research Development & Coordination at Telespazio. He is Member of il Quadrato della Radio, Member of IEEE, Member of AEIT. He taught Radio technologies, Communications Theory, Statistical Theory of Communications in different Italian universities. Currently he teaches Radio Mobile Transmissions at university of Rome 'Tor Vergata'.

Michael Segal finished BSc, MSc and PhD degrees in computer science from Ben-Gurion University of the Negev in 1994, 1997, and 1999, respectively. During a period of 1999–2000 Dr Michael Segal held a MITACS National Centre of Excellence Postdoctoral Fellow position in University of British Columbia, Canada. Dr Segal joined the Department of Communication Systems Engineering, Ben-Gurion University, Israel in 2000 where he currently serves as department's Chairman. He has over 60 publications in scientific journals and conferences. His primary research is algorithms (sequential and distributed), data structures with applications to optimization problems, mobile wireless networks, communications and security.