Integrated Broadband Wireless Network

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Abstract. Telecommunication systems based on wireless technology (Wi-Fi, WiMax, Sat DVB-RCS, etc.) offer more than others systems, the opportunity to provide a wide range of broadband services and applications. There are some circumstances where these systems contribute to solve the problem of need of communications such as, for example, for communication restoration during emergencies and catastrophic events as well as for communication services deployment in rural suburban areas typically affected by "digital divide".

This paper presents a proposal for an unique integrated wireless network system, mainly based on TCP-IP protocol, which provides a wide range of applications like voice, video, internet browsing, data access, etc.

A specific section of the paper is dedicated to WiMax technology and, to evidentiate the performances of this innovative technology, some results of the trials carried out in Italy in 2005–2006 by Fondazione Ugo Bordoni (FUB) and Ministry of Communications, are reported.

1 Communication Network Architecture

The main characteristics of the proposed integrated satellite and terrestrial communication network system (see Fig. 1), capable to provide broadband services for fixed and mobile users with high availability are:

- it allows the interoperability among existing terrestrial wireless networks (2G, 3G, WiFi/WiMax, Tetra, IP, etc.)
- it includes star/mesh satellite networks operating with transparent or regenerative transponders based on hub gateways interconnected with terrestrial networks.

1.1 Wireless and Satellite Network Integration

To give the possibility, for large communities of users, to access to IP applications and services on broadband networks, the Wireless Broadband Network (WBN) Architecture shown in Fig. 2 has been considered. The main blocks of this architecture are:

- Wireless Access and Distribution Network (WADN)
- Satellite and Wireless User Terminals (SWUT)
- Satellite Network Access Point (SNAP)

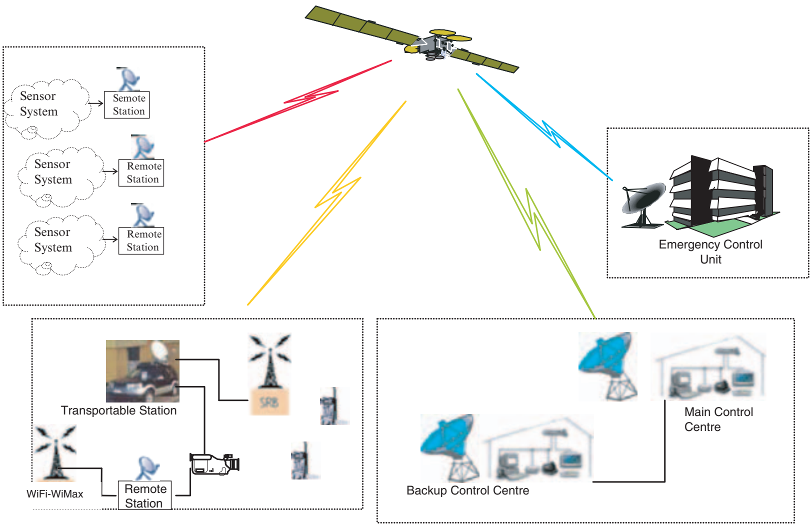

Fig. 1. Communication network bock diagram.

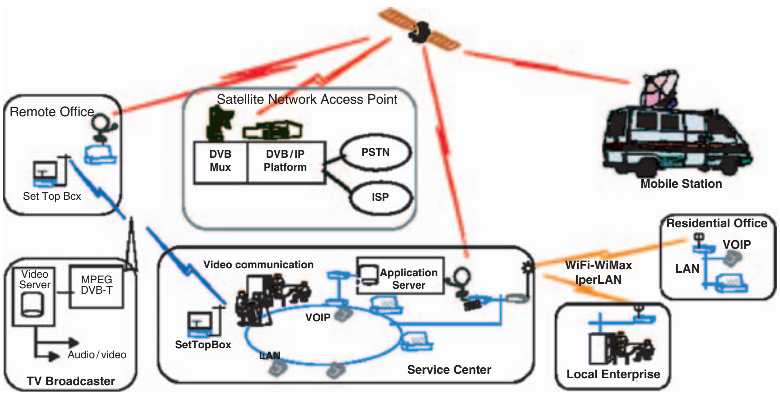

Fig. 2. Satellite and wireless network architecture.

- Mobile Integrated Station (MIS)
- Service Centre (SC)

A detailed description of these blocks will be given in the next paragraphs.

2 Some Applications and Services for the WBN

Typical applications for the WBN, described in the present paper, are

– communication restoration during emergency events;
– contribute to reduce the digital divide.

To better understand the peculiarities of these two applications a more detailed analysis is reported.

2.1 Applications and Services for Communication Restoration During Emergency Events

As far as the catastrophic events are concerned they are usually managed according to the following phases:

Phase 1 – during event: human and technical resources engaged for first aid;
Phase 2 – after event: communication resources restoration and management.

In particular, in phase 2, the restoration of the communication interoperability between involved areas is a primary objective. A multi purpose wireless IP network is able to guarantee a wide range of services, exactly where they are essential, in very short times. Typical applications and services are:

- IP Audio/Video communications by satellite via a mobile terminal between emergency areas and a central telecommunication gateway;
- IP Audio/Video communication in the emergency areas via WiFi/WiMax access points integrated in the mobile terminal and/or via TETRA and GSM networks;
- Localization and positioning management (closed and open loop). Maps transfer service performed by the mobile terminal;
- Human Health Monitoring HHM (life parameters) involved in hazard operations;
- Internet browsing, database access, file transfer and file sharing;
- Hospital Receptivity Information (HRI).

2.2 Applications and Services to Reduce the Digital Divide

The digital divide is still present in industrialized countries where the regional topography (rural and mountain areas) does not allow fast communication infrastructures such as fibre optic or ADSL technologies, capable to provide broadband services. In these cases the broadband service demand can be granted by the use of wireless technologies which do not require large investment cost and long times for the implementation.

The following wireless technologies could be applicable for the above mentioned cases:

- DVB RCS satellite technologies constituting the network backbone between rural areas and the tlc gateway;
- Wireless Local Loop, WiFi, HiperLan and WiMax technologies for the broadband service local distribution;
- Terrestrial Digital TV for downlink channel distribution

For example, the DVB RCS satellite terminals, operating in the Ku band, can provide data access up to 38 Mbps in download and up to 4 Mbps in upload.

This data rate capability can allow the implementation of the following services:

- Administrative Management Services
- Emergency Services
- Service distribution to the user demand via WiFi-WiMax technologies

The broadband data services shall be based on a unique standard protocol TCP/IP and the useful data rate could be: 50 Mbps for Base Station and 10 Mbps for User Terminal.

3 Wireless Network Elements

The Main Wireless Network Elements of a Broadband Telecommunication Network are the following:

- Satellite Network Access Point (SNAP)
- Wireless Access and Distribution Network (WADN)
- Satellite and Wireless User Terminals (SWUT)

The functions of these Network Elements are described in the following.

3.1 Satellite Network Access Point (SNAP)

An emergency or rural satellite network shall be a mixed of different architecture/technologies in order to be flexible during the deployment to the different circumstances. Transparent and/or re-generative satellite could be used jointly with star and/or mesh network technologies for ground/user terminals.

The main satellite networks elements of a SNAP will be:

- Satellite Network Control Centre (SNCC);
- Satellite Network Traffic Station (SNTS) usually named Hub Station;
- Telco Network Gateways (TNG) co-located with the SNTS.

The SNCC and the SNTS are normally co-located in the Satellite Operator Centres and provide three main functions:

- The Satellite Network Control
- The Traffic Management
- The connections between the User Terminals (UT) and the Telco Network Gateways (TNG).

The SNCC and SNTS do not need to be allocated in the Recovery areas but these are existing facilities providing a fast access to the TLC Network via the Service Network Elements (SWUT, MIS and SC).

The standardized technology for SNCC-SNTS stations is the DVB RCS providing a DVB IP download channels bit rate of 38 Mbps and an upload return channels max bit rate of 4 Mbps. The DVB IP channel is a TDM carrier while the RCS access is performed in TDMA in order to allow the connection to the SNCC-SNTS Station for hundreds of User Terminals.

3.2 Wireless Access and Distribution Network (WADN)

The WADN is the access and distribution network we propose and it is based on a very attractive solutions of WiFi and WiMax technologies. A more detailed description of these technologies is reported in the following sections.

3.3 Using WiMax Technology

While many technologies currently available for fixed broadband wireless can only provide line of sight (LOS) coverage or, alternatively, have good building penetration performance but small coverage area, the WiMax technology has been optimized to provide excellent, large, non line of sight (NLOS) coverage. WiMax's advanced technology, just following the preliminary technical features declared by manufacturing companies, provides the best performances in any of the above mentioned link conditions – large coverage distances of up to 50 kilometres under LOS conditions and typical cell radii of up to 5 miles/8 km under NLOS conditions. This results have been partially confirmed by the results obtained during the trials carried out in Italy during 2005–2006 by FUB and Ministry of Communications in collaboration with the principal manufacturing companies of this technology which are reported in the last paragraph of this paper.

3.4 Network Elements

The Standard BS will be Equipped With:

– Basic WiMax implementation;
– Standard RF output power for a lower cost BS.

The full featured BS will be equipped with:

– Higher RF output power in respect to the standard BS;
– Tx/Rx diversity combined with space-time coding and MRC reception;
– Sub-channelling;
– ARQ.

Both the standard and full-featured base stations can be WiMax compliant. It is important to understand that there are a number of options within WiMax that give operators and vendors the ability to build networks that best fit their application and business case.

3.5 WiMax/WiFi Network Connection Module with Gateway Capabilities

WiFi hot spots are being installed worldwide at a rapid pace. One of the reasons which obstacles hot spot growing is the lack of availability of high capacity, cost-effective backhaul solutions. The problem could be overcame with the use of WiMax technology which could also help in fill up the coverage gaps among WiFi hot spot coverage areas.

WiMax offers a useful throughput better than 60 megabytes per second (Mbps) in a 20-MHz channel. This is more efficient if compared with the 25 Mbps available in the standards 802.11 a or g. The quality of service of WiMax is also superior, thanks notably to more sophisticated control over transmission, which guarantees a good level for the services offered. Thus, there will be limited latency delays, which prove to be essential, for example, in transmitting Voice over IP. It also provides better security levels as, the final equipment, must be identified before being connected to the network.

Furthermore WiMax technology should be substantially less costly if compared with other ones proposed today under proprietary systems. This is explained by the peculiar characterics of the devices as well as with the competition among suppliers once the standard has been adopted.

3.6 WiFi Ground Signal Distribution Point

The WiFi (802.11b/g) radio signal is mainly a line-of-sight signal, meaning it doesn't bounce off things like walls, ceilings, or even the atmosphere, as some radio signals do. But it can get through some opaque objects like walls, ceilings, and floors under certain conditions.

Those certain conditions depend on how electrically dense the barriers are. A typical drywall between offices isn't normally a problem, but conduit, plumbing, or steel studs can increase the density. Going through several of these walls can defeat the signal quickly.

4 Service Network Elements

The Main Service Network Elements of the proposed Broadband Telecommunication Network are the following:

- Satellite and Wireless User Terminal (SWUT)
- Mobile Integrated Station (MIS)
- Service Centre (SC)

The functions of these Service Network Elements are described here below.

4.1 Satellite and Wireless User Terminals (SWUT)

The satellite terminal is a two way, bandwidth-on-demand broadband VSAT. The forward channel provides a total capacity of 60 Mbps, while return channel to the hub can transmit up to 4 Mbps. For increase return channel throughput and reduce the satellite bandwidth employed to transmit, it use DVB-RCS system.

The main features of a satellite terminal are shown in Table 1.

Table 1. Satellite and wireless terminal feature.

Return Channel
Format: MF-TDMA
Symbol Rate: 156, 312, 625 Ksps, 1, 25, 2, 5 Msps
Turbo coding: DVB-RCS compliant
Modulation: QPSK
Forward channel
Format: DVB/MPEG-2 TS, DVB-MPE for IP data
Symbol rates: 2, 5 to 36 Msps
FEC: DVB compliant R/S and Convolutional
Modulation QPSK
Performance
Protocols: TCP/IP, UDP/IP, IGMP, RIP, 1&2, IP QoS support
TCP accelerator

4.2 Mobile Integrated Station (MIS)

The concept of a Mobile Integrated Station MIS is to bring communication broadband services in the Recovery areas either for emergency or telemedicine applications. A typical Mobile Integrated Station is shown in Fig. 3. The MIS station is normally equipped with:

– Satellite Access to the SNCC-SNTS Station and to the TNG
– Wireless Access for Service Distribution for local users
– Audio/Video Recording and Encoding equipment
– VoIP gateway

Typical offered applications are:

- Voice over IP VoIP
- Audio/Video Communications
- Emergency and Telemedicine Services
- News Distribution for Emergency

Fig. 3. Mobile integrated station layout.

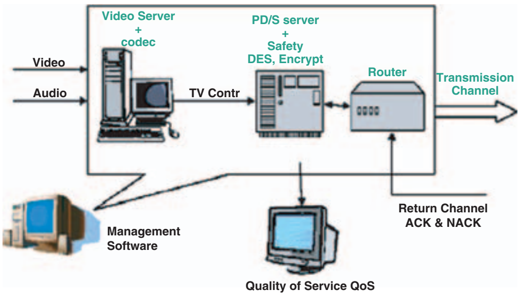

Fig. 4. Regia centre.

4.3 Service Centre (SC)

The Service Centre is normally co-located in the Service Coordination Centres and allows the Access to standard DVB IP platforms capable to provide a wide range of applications. Typical offered applications are:

- Voice over IP VoIP
- Web TV e Business Television
- Distant Learning
- Emergency Services for Telemedicine
- Web Hosting
- Application Hosting
- News Distribution

Furthermore the Service Centre could include a Regia Centre (Fig. 4) where the Live Events Contributions via SNG Mobile Station can be collected and provided to local Broadcaster for Information Dissemination.

5 Some Results of the Italian Wimax Trials

The recent development of broadband wireless technologies has raised the attention of Italian ICT operators in respect of the new WiMax technology, able to allow the implementation of broadband wireless networks in point-to-multipoint topology with metropolitan extension.

For this reason the Italian Ministry of Communication (MINCOM) has authorized a technological trial to be carried out in different Italian Regions and Cities. The trial will involve different WiMax manufacturing companies as well as the official Italian resellers and is planned to be concluded at the end of June 2006. FUB, R&D company supporting the MINCOM, will lead and monitor all the trials.

The trials have been allocated in the 3.4–3.6 GHz band that has been identified in Europe as the core-band to be licensed to offer Wimax services in the future.

The instances of authorized trials have been 53, and these have been conducted in Piemonte, Valle d'Aosta, Sicilia, Sardegna, Abruzzo and in the cities of Roma, Milano, Parma and Arezzo.

The participation of the main manufacturers (Siemens, Alcatel, Ericsson, Nortel, Marconi Communication, Selex, etc.), have made possible to test a large number of WiMax devices available on the market.

Different conditions of propagation, including Line-Of-Sight (LOS) or Non-Line-Of-Sight (NLOS), as well as a variety of scenarios, such as urban, mountainous, rural, coastal, etc., have been considered. The purpose has been the evaluation of the existing technology and the verification of their employment to solve the complex problem of "digital divide".

The network architectures considered cover a large selection of cases including the point-to-multipoint configuration and the backhauling configuration where two or more base-stations are connected in a chain to establish a transport backbone network.

A considerable number of system parameters have been evaluated during the trials. The maximum transmit power (EIRP) allowed for the trial has been fixed at 36dBm. This value has been fixed in agreement with the Ministry of Defence that is, actually, the licensed Italian entity to utilize the 3.4–3.6 GHz frequency band.

Some test results of mixed trial conducted in suburban and rural areas are shown in Table 2.

Table 2. Sample test results.

a) Experimental results from Marconi Communications

Measurements in a mixed urban/rural environment (distance BS-SS: 2,95Km/condition NLOS)

Frame size (bytes)	Throughput (Kbps)	Latency RTD (ms)	Jitter (ms)
1518	120,95	77	5,2 uplink
1518	1021	66	4,1 downlink

Measurements in a mixed urban/rural environment (distance BS-SS: 6,65Km/condition LOS)

Frame size (bytes)	Throughput (Kbps)	Latency RTD (ms)	Jitter (ms)
1518	417,85	46	9,4 uplink
1518	7749	33	4,1 downlink

b) Experimental results from Alcatel

Measurements in urban environment (distance BS-SS: 1,2Km / condition NLOS)

Frame size (bytes)	Throughput (Kbps)	Latency RTD (ms)	Jitter (ms)
1500	4764	32	4,1 uplink
1500	9946	32	2,2 downlink

Measurements in extra-urban environment (distance BS-SS: 6,5Km / condition NLOS)

Frame size (bytes)	Throughput (Kbps)	Latency RTD (ms)	Jitter (ms)
1500	4864	32	3 uplink
1500	9958	31	1,9 downlink

6 Conclusion

The architectures for satellite and wireless recovery networks capable to carry out broadband applications are day by day evolving due to three main factors:

- The service convergence to IP protocols
- The wireless evolution of WiMax technologies
- The satellite evolution of DVB RCS technologies

The possibility to plan Recovery Networks for Emergency Communications and Digital Divide Reduction is nowadays a reality allowed by the wireless technology convergence and it could be carried out in short time and without large investment costs.

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