Chapter 4. TETRA and GSM over satellite

TETRA and GSM over satellite have been addressed a number of times in the first three chapters of the document. Their vital roles in the present project are well worth an entire chapter dedicated to it. Although a lot of research on transmitting data over satellite communications has been carried out over the past few years for technologies such as GSM, TETRA is still quite an unexplored field. This chapter is pretty much based on the paper previously mentioned [1].

4.1 TETRA over satellite

Despite being the least known of all the technologies involved in e-Triage, TETRA plays a crucial role in it. Its trunked architecture perfectly fits e-Triage requirements, for the entire system will have to support distribute features as well as ensure fully centralised capabilities (e.g. allocation of priorities). This mixture of two different topologies is not an easy task to deal with, and only an easy-to-use and appropriate management system can provide a suitable solution. TETRA solves this by entirely controlling and maintaining the system by means of a software kit.

This being true, the fact is that TETRA was not chosen simply for its architectural resemblances with e-Triage, but rather a requirement of the police and fire brigades services since the technology is becoming a standard for these types of services. This said, the reasons behind its use lie essentially in two points: the duration of time-delays, the level of security and the extra services provided by this technology. These extra services have mainly to do with the variety of calls available in TETRA in comparison to other mobile technologies such as GSM or UMTS, and have already been explained at length in the section 3.8. The following list summarises all these points.

- Faster call set-up, or the time between the calling mobile presses the calling button until the first voice frame is received at the called mobile. While in GSM this time typically varies from 3 to 4 seconds, in TETRA is always below 300 ms, with a typical duration of 230 ms¹. This time fully meets emergency situation requirements.
- Group, acknowledged group and broadcast calls. While GSM only provides individual calls, TETRA also allows users to maintain interactive calls or broadcast scenarios (point to multipoint). These features can be of great help when it comes to organising tasks among big groups of people such as first responders or security forces.
- Priority calls. TETRA management software², included in the e-Triage software, contains a priority system based on profiles. These profiles allow the system to prioritise the traffic from certain users depending on the system requirements (e.g. in a simplified scenario of e-Triage, medical aid calls might go first, then security calls and then civil calls).
- Much safer encryption. GSM was designed with a moderate level of security. Some of its loopholes have been exposed over the past few years and are now well-known. The lack of an end-to-end security mechanism or the relatively easy task of cloning a SIM card are some of its weaknesses. To overcome these weaknesses it was therefore necessary to add 'patches' to the current technology. One of the e-Triage priorities is security. In this sense, TETRA provides several additional security mechanisms that ensure total encryption throughout the entire communication link.
- Greater coverage. Theoretical coverage goes up to 58 km. In practice, it varies on the type of environment (urban/semi-urban/rural areas). Note that TETRA provides the

¹This requirement is valid within a single TETRA cell. It is unreal to expect times in the order of 300 ms in long-distance communications (due to propagation delay), not to mention if satellite links are involved.

 $^{^{2}}$ Recall TETRA is a computer-controlled system. Therefore, it is utterly managed and controlled by means of software tools.

greatest coverage of all the different technologies used here, and thus the least number of cells to be deployed corresponds to TETRA.

• The Direct Mode Operation (DMO), more commonly known as the 'walkie-talkie' mode, is probably the most significant feature that distinguishes TETRA from other cellular networks. It allows users to communicate among each other without actually using the trunked network. This implies, amongst other features, that communication between terminals beyond the network coverage is possible. Two mobiles can establish communication within theoretical distance up to 1 km.

4.1.1 TETRA Interfaces

As it's been explained at length in Section 3.4, TETRA is exclusively defined in terms of its interfaces. In other words, in TETRA the internal architecture is designed by manufacturers completely up to their preferences. TETRA's set of standards specify six different interfaces, the most important of which are the Terminal Equipment Interface (TEI), the Direct Mode Operation DMO), the Inter-System Interface (ISI) and the Air Interface (AI). They have already been illustrated in Figure 3.4.

As shown it was shown there, the interface TETRA uses to communicate with other TETRA networks is the Inter-System Interface. This is the interface to be taken over satellite. At this point, designers face two options: (a) use the corresponding standardised interface, ISI, or (b) use a non-standardised option such as A-bis. *A priori*, any of these two interfaces can be used over satellite, but a deeper look proves that a sensible choice is crucial, for a bad decision can turn out in a faulty operation of the whole system.

Roughly speaking, there are two factors to be taken into account in a disaster context. One is the terrestrial situation of the existing infrastructure; the other the standardisation. ISI can be useful in a scenario where there's already an existing infrastructure deployed but has been damaged up to some extent. However, if there's no pre-existing network (e.g. as in a military action in a foreign country), A-bis is to be taken into account. But, it is necessary to bear in mind that A-bis is not a standardised interface. On the one hand, this means an advantage first to manufacturers, for they are able to freely design an interface matching their own specifications and at a low-cost, and secondly to users, who will pay less money for the final product. On the other hand, a non-standardised interface implies that the equipment from a particular manufacturer won't be able to communicate with others. This can cause a big amount of trouble in case, say, two humanitarian aid groups from different countries (most likely using different technologies) try to establish a communication in order to coordinate tasks. As for ISI, this problem simply cannot come up, for ISI ensures interoperability irrespective of the manufacturer.

So, simply put, using TETRA over satellite must provide, above all, interoperability between users from different sources. In this sense, A-bis does not provide sufficient interoperability whereas using ISI ensures total operability at the expense of a slightly higher investment for manufacturers. The trade-off, then, clearly favors ISI.



Figure 4.1. TETRA architecture in e-Triage.

Fig. 4.1 illustrates a possible scenario with three TETRA cells deployed in the disaster area. For simplicity, GSM and WLAN networks have been left out. A closer look at the disaster area shows a single satellite connection with the remote area. This does not mean that there'll be only one CPCE able to communicate via satellite, but since the satellite bandwidth is the most scarce resource, the most likely solution is to redirect the

IP packets inside the disaster area (notice that all the CPCEs are connected via WLAN) in order to reduce the number of ECS/CPCEs in charge of sending data over satellite³. In the particular example shown in the figure with three TETRA networks, a single satellite link should do.

Notice also that in every single CPCE there's a router where all data from the different technologies (GSM, TETRA and WLAN) converges and then is sent over all together, irrespective of its actual origin. This process is relatively easy (and completely transparent to users) due to the IP-based nature of the three technologies. In the disaster-safe area, the e-Triage Gateway (e-Triage GW) will be in charge of demultiplexing these IP packages and redirecting them to their corresponding base stations. Once processed, data packages can end up in the Public Switched Telephone Network (PSTN), the Integrated Services Digital Network (ISDN), other TETRA networks, etc. In other words, TETRA mobiles are perfectly capable to call and send data to other 'twin technologies' as GSM or UMTS.

4.1.2 Satellite Link Connections

In addition to the standard used over satellite, it is critical to choose a sensible satellite link connection with VSAT. Two options are proposed:

- Direct VSAT to VSAT link. The data sent over satellite goes straight to the VSAT terminal at the receiver site. This entails a round trip delay of roughly 250 ms.
- Earth hub. The data is sent over an earth hub, which increases the delay. In this case the total time will approximately double the previous value, 500 ms.

In short, a direct VSAT-VSAT link is preferable. In order to reduce the most important delay of the overall system, the satellite link, a Performance Enhancing Proxy (PEP) can be implemented over ISI. Very simply, a PEP is a software that breaks down the end-toend TCP connection into multiple connections to improve the overall performance. PEPs must be totally transparent to end-systems, which in other words means that the end users

³In practice, since all ECSs and CPCEs are to be designed and built in an 'assembly line' fashion, they are bound to contain the same elements and therefore able to carry out the same tasks. However, in order to reduce costs, some elements might be omitted (e.g. VSAT antennas in some CPCE).

must not be aware of its use. Since the project is still in the design phase no results are available on the issue for the moment.

4.2 GSM over satellite

In a commercial GSM network, the BTS is connected to a BSC through the A-bis interface. From the BSC, the core network is interconnected via the A and Gb interfaces to the Mobile Switching Center (MSC) and Gateway GPRS Support Node (GGSN) / Serving GPRS Support Node (SGSN). A complete GSM/GPRS architecture is shown in Figure 4.2. The A-bis interface is usually a radio link, whose latency is a few milliseconds.



Figure 4.2. General GSM architecture

The GSM/GPRS architecture for e-Triage is depicted in Fig. 4.3. The selected BTS is used as radio front-end towards the GSM mobile phones. The BTS features one GSM radio carrier with 8 GSM channels. It is connected via Ethernet to the router which hosts the Terminal Side GSM Server (TSGS) software. The TSGS then forwards the GSM/GPRS signaling and traffic via the satellite terminal and its corresponding Ground Station to the Network Side GSM Server (NSGS). Finally, the traffic is sent from the NSGS to the BSC via Internet.

The selected BTS implements the A-bis interface over IP networks, encapsulating all traffic and signaling into IP datagrams. This means that the A-bis traffic can be routed



Figure 4.3. GSM over satellite architecture

through conventional IP networks, including satellite-based ones. The Base Station System (BSS) functions are divided into a BSC at the disaster site and a backbone BSC at the disaster-safe side (see Figure 4.3 again). The TSGS terminates the signaling and controls the BTS, whereas the NSGS performs data transcoding and routing to the core network elements. It uses the Gb interface to connect to SGSN/GGSN and A standard interfaces to connect to the MSC. The NSGS is a PC-based server behind the e-Triage gateway. The GSM/GPRS core network at the provider site comprises a Software BSC/MSC, which also hosts a Media Gateway Service (MGS) for transition from IP to GSM/GPRS networks, and a Short Message Service Center (SMSC) for proper Short Message Service (SMS) support.

Although TSGS and NSGS perform some functions of the BSC and BTS respectively, the BTS will not work if the BSC is not reachable, i.e. if the satellite/UMTS connection is not available. In that case, the mobile devices will show network unavailability. Related extensions for independent local communications are foreseen in future extensions of the solution. The setup is supported by a management and configuration tool which adapts the standard GSM/GPRS solutions to e-Triage specific needs (such as customized network identification, SMS broadcast messages, etc.). The GSM/GPRS system in e-Triage is scalable, i.e. more than one BTS can be used in the disaster area and they are all connected to the same NSGS and BSC. To avoid interferences, the BSC assigns the available channels to the BTSs accordingly. In case that one cell does not have external connectivity, it will try to connect to other cells via WLAN and access the NSGS and BSC through them.

In the following, three methods to improve the GSM performance over the satellite are described, which are signaling modification, multiplexing and compression of the calls and satellite link handling. These methods are needed because of the satellite delay characteristics, which may prevent GSM working, and to reduce satellite bandwidth, which is expensive.