SATIN MULTICAST/BROADCAST ORIENTED ARCHITECTURE AND S/T-UMTS TERMINAL AND NETWORK LEVEL INTEGRATION

L.Zaccheo[1], T. Severijns[1],W. De Win[1], M. Dieudonne[1], K.Narenthiran[2], M.Karaliopoulos[2], B.G.Evans[2], M.Mazzella[3], G.E.Corazza[4], A.Polydoros[5], I.Mertzanis[6] and P.Philippopoulos[7]

[1]Agilent Technologies, Wingepark, 51 B-3110 Rotselaar, Belgium
Tel: +32 16 46 97 11, Fax: +32 16 44 54 81, Email: michael_dieudonne@agilent.com

[2]University of Surrey (UK), [3]Alcatel Space (France), [4]University of Bologna (Italy),
[5]University of Athens (Greece), [6]Space Hellas (Greece) and [7]OTE Consulting (Greece)

Abstract: *This paper discusses three different levels of integration, service, network and terminal level, between T & S-UMTS and how they are related to the customer service requirements, satellite market, and business issues as well as to the terminal cost. It is also explained how the geographical and service complement concepts affected the SATIN architecture definition. Different service coexistence scenarios are described and the corresponding terminal architecture scenarios are proposed. Possible network integration issues are highlighted as well.*

1. INTRODUCTION

The growing demand for access to multimedia services anytime and anywhere is the key driver of 3G systems. But it is difficult to satisfy the anywhere concept without deployment of satellites. In the past, personal mobile satellite systems have been developed in isolation from the terrestrial mobile systems and stood competitively against them as they attempted to provide a similar set of services. This is one of the main reasons for the failure and delay of the 2G mobile global satellite systems (e.g. Iridium, Globalstar and ICO). The failure is also partially due to the poor market prediction, the limited payload flexibility and the terminal complexity. A closer integration with terrestrial systems may reduce significantly the implications of the latter issue.

In general, the integration between satellite and terrestrial systems can be achieved at three different levels, service level, network level and/or terminal level. The degree of network-level integration influences the roaming capabilities of the terminal and introduces a number of issues related to the system operator(s). Terminal level integration has a major impact on the size and the price of the terminal. Therefore, while specifying the access stratum and defining the way the selected services will be implemented, special attention should be given to the respective possible constraints on the level of integration achievable in practical terminal design. This paper will mainly focus on the issues related to the network and terminal level integration of the two components of UMTS in the light of the SATIN architecture scenarios.

2. GEOGRAPHICAL AND SERVICE COMPLEMENT SCENARIOS AND SATIN ARCHITECTURE

There seems to be a general agreement within the European satellite community upon the *complementary* role that S-UMTS should play with reference to T-UMTS. Mainly, two different complementary approaches, called geographical- and service- complement are considered in SATIN [1] as explained below.

2.1 A geographical complement / early service proposition approach

Geographical territories can be divided into regions with or without T-UMTS coverage. Areas not adequately covered by T-UMTS include physically isolated regions (*coverage extension*), gaps of T-UMTS network (*coverage completion*) and areas where telecommunication systems permanently, or temporarily, collapse due to disaster or conflict (*disaster-proof availability*). A variation of the latter would be the absorption of excessive traffic, while optimising the dimensioning of terrestrial infrastructure (*dynamic traffic management*). Moreover, S-UMTS could be deployed in areas where there is no infrastructure yet, for the purpose of testing the potential of an emerging market for new service propositions. During transitory phase from 2nd to 3rd generation, satellites may offer day-one global roaming solutions whereas terrestrial UMTS is more likely to be deployed firstly over limited 'islands' of coverage. Hence there would be an opportunity for an early development of worldwide multimedia services (*rapid deployment*). Outside T-UMTS coverage areas S-UMTS offers the same set of services provided by T-UMTS. The complementary role lies mainly - as its name suggests - in the fact that it can expand the reach of T-UMTS services in these areas.

2.2 A service complement / "close co-operative" approach

The evolution of the Internet and the increasing demand for multimedia services are likely to favour the dominance of multicast / broadcast services in the near future. So far the lack of cheap and efficient point to multipoint transfer mechanisms, and the traffic costs of pure point-to-point solutions have restricted the wide use of multimedia services. In this approach, the vision for S-UMTS is not to attempt to offer voice-based or interactive services, being less efficient as compared to the terrestrial networks, but to focus on the provision of multi/broadcast services, where there is the potential to provide them in a more cost-efficient manner. Satellite systems may offer a complementary solution, with a possible long-term impact to the way in which multicast data is delivered over the Internet.

2.3 SATIN approach and the reference architecture

Considering the above two complementary approaches and market and business analysis [1], it has shown that multicast and broadcast services constitute a promising, viable business case for the satellite systems.

Based on the above conclusion, satellite characteristics and T & S-UMTS integration, generic system architectures were proposed in [1] featuring direct access or indirect access to the satellite (Figure 1).

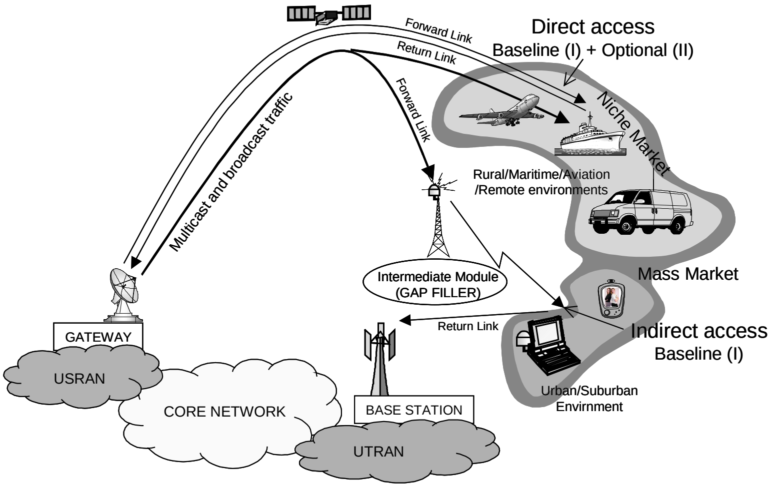


Figure 1: SATIN Reference Architecture

In the indirect case, the intermediate module repeater (IMR) [2], also called gap filler was introduced in order to guarantee the coverage of satellite within urban areas and inside the buildings. In fact these two scenarios can be mapped to the niche and mass-market requirements as shown in Figure 1 considering short term and long-term deployment of the satellite systems.

3. SERVICE COEXISTENCE AND CUSTOMER REQUIREMENTS

Before one can define the required integrated network capabilities and terminal transceiver configurations and capabilities for dual S/T-UMTS mode operation, it should first be clear what could be the coexistence of the services supported by the different access networks. In order to limit the number of service coexistence scenarios, a high-level division of services has been defined:

- **A Services:** Services other than Multimedia Broadcast & Multicast services (MBMS)
- **B Services:** Multimedia Broadcast & Multicast services (MBMS), standardized currently with in 3GPP [3].
- **C Services:** Paging - although paging cannot be seen as a real service, it is a procedure that supports services and it must be able to coexist in time with other services.

Whether basic UMTS services and MBMS should coexist in time is mainly determined by the communication needs of the users and is not so much driven by technical factors. However, the way both services coexist will have a direct impact on the required network level integration and terminal configuration. Two service coexistence scenarios, the concurrent and the time-exclusive scenario are defined below.

Concurrent Scenario: in this scenario the user terminal supports the simultaneous delivery of both basic UMTS services and MBMS as shown in Figure 2. In this scenario it would be possible to receive broadcast or multicast services as background processes while making e.g. a phone call.

Taking the aforementioned assumptions into account, the following rules apply:

- A parallel receiver architecture is necessary to receive simultaneously a terrestrial and a satellite link. Hence, no significant reuse of receiver hardware is possible.
- Paging or interactivity to support MBMS can be provided through the terrestrial access

Time Exclusive scenario: in this scenario the user terminal doesn’t support the simultaneous delivery of both basic UMTS services and MBMS.

Taking the aforementioned assumptions into account, the following rules apply:

- A reconfigurable receiver architecture capable of switching between terrestrial and satellite mode can be used.
- Paging should be provided through the satellite access network when the user terminal is in MBMS mode, but in absence of the complementary satellite transmitter, the terminal is lacking in interactivity with the network.

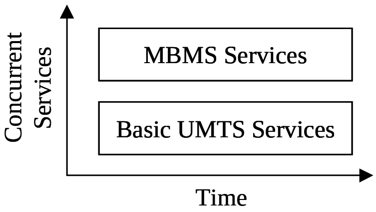


Figure 2: Current Services Existence

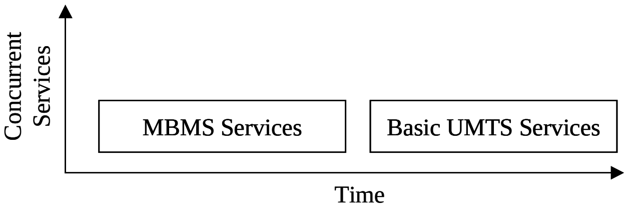


Figure 3: Time Exclusive Service Existence

4. NETWORK CONFIGURATION

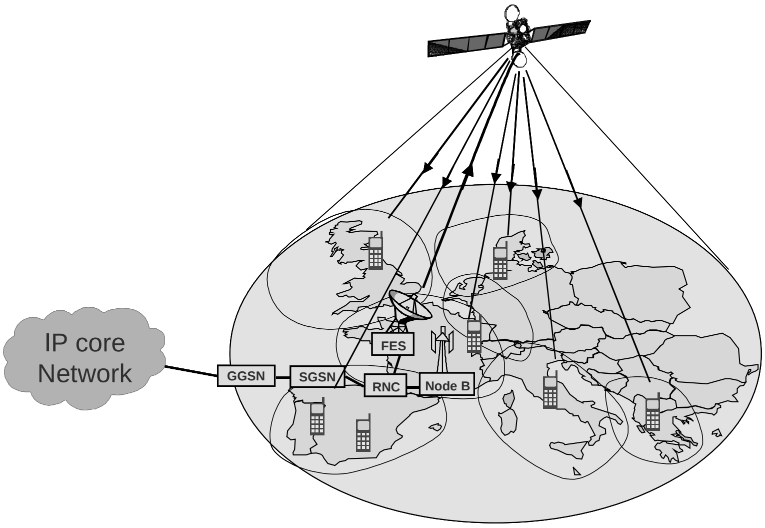
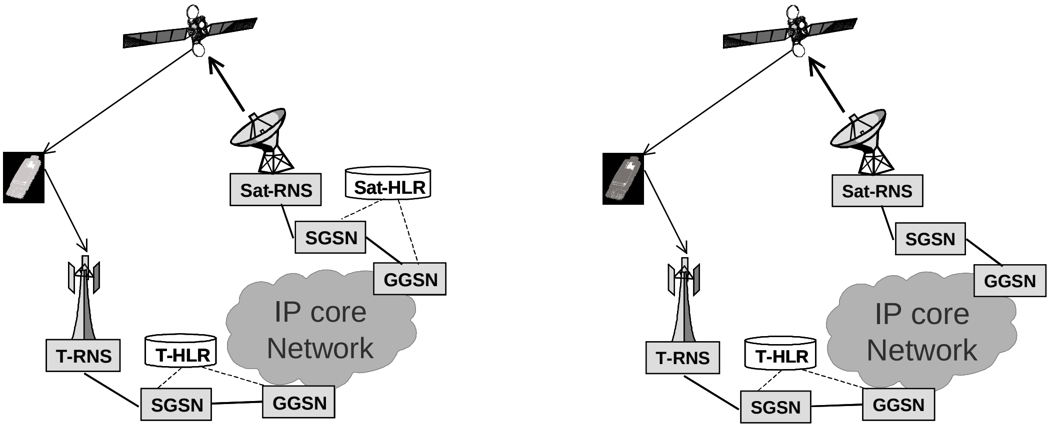


Figure 4: Network architecture and FES distribution

A possible arrangement for European regional coverage of the seven spot beams is shown in Figure 4. Here each spot beam is equivalent to a cell in T-UMTS. Considering the size of the spot beam, it may be possible to assume that the routing area (RA) of the packet based S-UMTS is of the same size as the cell. In general, the RA can include several cells/spot beams and its size depends on the signalling load of the location update and paging procedures based on the mobility of the users. It is also assumed here that a single gateway handles the whole satellite network and that the system is operated by a single satellite system operator. Subscribers of different terrestrial mobile operators can access the satellite services according to the agreements between the terrestrial and satellite operators. Regarding paging, when terminal receives multicast and broadcast service, there are two possibilities. The paging can be done via satellite if the terminal (whether the terminal is inside the T-UMTS coverage area or outside) is dual-mode. If the terminal is parallel-mode, then it can be paged via the T-UMTS network, if the terminal lies inside the T-UMTS coverage area, or via satellite when the terminal is outside the T-UMTS coverage. If the terminal has to be paged via satellite, then the paging message comes to the home network of the terminal and has to be re-routed to the FES.

Since our reference is a dual/parallel mode terminal within a system architecture designed for the service-complement approach, both T-UMTS and S-UMTS networks are involved in the satellite-specific procedures. The question here is whether T-UMTS and S-UMTS needs to have different user databases or a single one. Since the T-UMTS services are considered as core services by most of the users, all the terminal information is contained in the T-UMTS databases anyway. The respective -architectural- decision mainly depends on the potential signalling required between the T & S-UMTS networks for the support of the system procedures. Two possible scenarios are shown in Figure 5.

In the first case, the information related to users of satellite services is stored separately in the T & S-UMTS databases. When the user contacts the T-UMTS network for the satellite services, the SGSN directly contacts the T-HLR to obtain user information for authentication purposes. Likewise, when the UE contacts the satellite directly, the SGSN does not need to contact the T-HLR but rather directly contacts the S-HLR. In the second case the database in T-UMTS is common for both T & S-UMTS networks. Therefore irrespective of whether the terminal contacts the satellite or the T-UMTS Node B, the authentication should go through the T-HLR. In both cases the satellite operator leases the resources of the satellite to the terrestrial operator and the latter makes use of them according to its own needs (traffic load, service requirements, resource availability). These two different database architecture realisations are discussed purely from the registration and authentication signalling point of view.



Case 1: T & S-UMTS keeping the UE information separately

Case 2: S-UMTS depends on the T-UMTS UE database

Figure 5: Possible Database Architecture Scenarios

The decision as to which network (T/S-UMTS network) the multicast/broadcast content is routed to, depends on the size of the multicast group and the QoS required as well as the load of the terrestrial network.

5. TERMINAL CONFIGURATION

5.1 Hardware architecture options

In this section two different high-level hardware architecture options are proposed in order to implement the extra satellite capabilities in a terrestrial terminal transceiver. A dual mode terminal transceiver (T/S-UMTS) can be realised either by hardware duplication (parallel architecture) or by reconfiguration of the hardware already present in the UE for T-UMTS (reconfigurable architecture). This choice can be made in an independent way for the transmitter and the receiver chain.

5.1.1 Single mode hardware architecture

The reference architecture is a standard terrestrial UMTS transceiver, supporting all the terrestrial features like acquisition, tracking, measurements, diversity reception, several physical channels, etc. as specified in the 3GPP specifications.

5.1.2 Parallel hardware architecture

The parallel hardware concept involves additional *dedicated* hardware to support S-UMTS. An extra RF chain and baseband chip next to the T-UMTS chain assure the independent functioning of the satellite features in the UE, i.e. this terminal is able to receive and/or transmit from/to the T-UMTS and the S-UMTS radio access networks *concurrently*.

5.1.3 Reconfigurable hardware architecture

The reconfigurable hardware concept has in the ideal case only one hardware chain. To support both radio access networks (in a time division manner) reconfigurability is of course mandatory. The RF chain as well as the base band chip is shared between the two modes in a time division manner. To be able to do this, a highly flexible architecture is necessary, and an S-UMTS specification as close as possible to the T-UMTS standard is advisable.

A complete reconfigurable approach will however be technically impossible, especially for the RF part. For example, some dedicated filters and power amplifiers will be necessary due to the differences in frequencies.

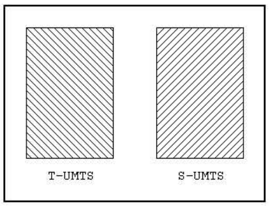


Figure 6: Parallel hardware architecture

☺	☹
Supports concurrent operation	High space occupation
Requires less flexible hardware	High cost

Table 1: Main benefits and disadvantages of a parallel approach

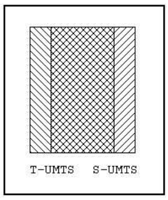


Figure 7: Reconfigurable hardware architecture

☺	☹
Smaller size	Concurrent operation impossible
Lower cost	Not possible for some RF parts

Table 2: Main benefits and disadvantages of a reconfigurable approach

5.2 Terminal transceiver configurations

It is possible to have different hardware implementations for the transmitter and the receiver, leading to several terminal configurations with different capabilities.

The choice of the receiver and transmitter type influences heavily the cost of the transceiver, but also the terminal capabilities in terms of connectivity and therefore also in terms of supported services. For this reason, more attention will be given to the connectivity capabilities of the different configurations in this section.

In accordance with the system architecture that emerges from the SATIN project, the single satellite mode solution is not investigated. The terrestrial single mode will be the reference solution for the evaluation. By combining the single, the parallel and the reconfigurable mode for the receiver and transmitter parts, different user terminal configurations can be identified.

Only the four terminal configurations relevant to SATIN will be discussed together with the terrestrial single mode terminal (reference scenario). These in fact constitute a further subdivision of the baseline and optional terminal scenarios that where already defined within SATIN.

5.2.1 Terrestrial terminal transceiver (reference scenario)

This kind of transceiver is the reference for the cost evaluation. It has only terrestrial capabilities and it supports a bi-directional T-UMTS operation. It means that this kind of terminal needs two different RF chains and baseband modules: one for the forward link and a second for the reverse link. No hardware will be shared and no satellite capabilities are implemented.

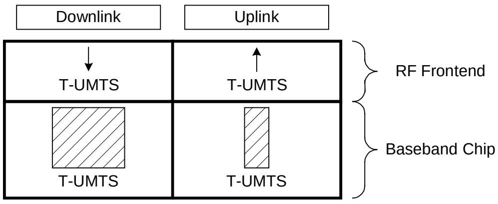


Figure 8: T-UMTS transceiver configuration (reference configuration)

The baseband chip is the simplest one considered in this study. It will support all the physical channels necessary for all the terrestrial services.

5.2.2 Baseline configuration with parallel receiver architecture

This transceiver can be connected with the terrestrial network via a bi-directional link while simultaneously receiving a signal from a satellite in the S-UMTS frequency band. In this case, the Tx part doesn't change from the reference scenario. The Rx part however needs to be extended with an S-UMTS module to be able to receive both signals from both radio access networks *at the same time*.

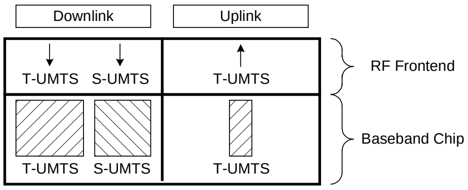


Figure 9: Baseline configuration with parallel receiver architecture.

Hence two downlink RF chains and baseband chips are necessary: one for the terrestrial and one for the satellite signal. The terrestrial part of the receiver will not change from the reference scenario. When a MBMS session is active, this type of terminal uses both radio access networks for its communication with the core network namely S-UMTS for the downlink data stream, T-UMTS for the reverse channels. The reverse channel is necessary for the MBMS set-up (e.g. for subscription, billing and data integrity reasons). Moreover, it could be necessary for supporting the S-UMTS downlink data stream. Inherently, a T-UMTS reverse channel needs a T-UMTS downlink for control/set-up of the uplink and the fact that the receive chains are separate has the advantage of being able to install the bi-directional link with the T-UMTS network at all times. Additionally, when in S-UMTS mode, paging could be done through the terrestrial network and simultaneous T-UMTS and S-UMTS services are possible with this kind of implementation.

5.2.3 Baseline configuration with reconfigurable receiver architecture

This terminal shares the downlink RF chain between the terrestrial and the satellite mode for the downlink. In this case, the terminal can set up the MBMS session through the terrestrial network and thereafter swap to satellite mode in order to enjoy one or more MBMS.

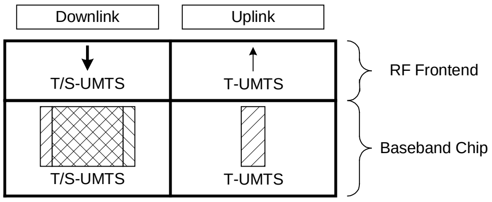


Figure 10: Baseline configuration with reconfigurable receiver hardware.

The "Exclusive T/S Downlink" terminal can't receive the terrestrial and the satellite signals simultaneously. In other words, for this terminal type *either* a bi-directional terrestrial link *or* a satellite unidirectional downlink is possible. If an S-UMTS downlink is considered to be operating concurrently with a T-UMTS uplink, this implies that *at the same time* a T-UMTS downlink must be available. This is because a T-UMTS uplink needs some interactivity for signaling, acknowledgements (e.g. power ramp-up procedure for RACH use), matters of synchronicity, etc., hence the uplink and downlink must operate in an alternate way if this type of architecture is used.

The satellite component is only there to support the MBMS services. Depending on the combined Rx/Tx configuration and the definition of the S-UMTS access scheme, it could be mandatory to receive T-UMTS *concurrently* with S-UMTS reception or be able to use bi-directional services, like voice, in conjunction with MBMS services and hence a reconfigurable approach is impossible.

5.2.4 Optional configuration with parallel receiver and transmitter architecture

This terminal is able to establish a bi-directional link with both the terrestrial network and the satellite network at the same time. This solution doesn't allow the sharing of hardware, so all four RF chains and baseband chips have to be completely separate and independent from each other. In the transmitter, the power necessary at the satellite section will be higher compared to the terrestrial section. To keep this transmission power within safety levels, the data rate of the reverse channels in satellite operation will be limited. This is the most flexible solution from a service point of view: it could be able to set up a MBMS session (or an other service) without the support of the terrestrial network, meaning the terminal can profit the wider coverage of the satellite. Also, because both radio access networks are isolated from each other, it is the most advantageous solution for synchronicity and transparency matters.

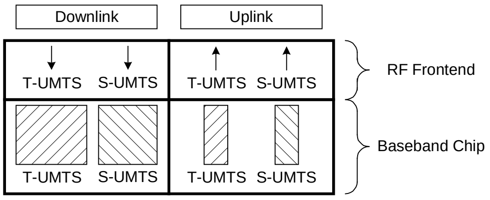


Figure 11: Optional configuration with parallel receiver and transmitter architecture

5.2.5 Optional configuration with reconfigurable receiver and transmitter architecture

This last option allows an exclusive bi-directional link either to the terrestrial network, or to the satellite network. In order to save space and keep the cost as low as possible, both the receiver and the transmitter are using a maximum of reconfigurable hardware.

A typical mode to work could be that the terminal is normally in terrestrial mode (terrestrial Tx and Rx) and it switches to satellite mode (satellite Tx and Rx) at the moment that it has to receive one or more MBMS services. In this case (as in the previous one) the terminal is capable of establishing a satellite bi-directional link and afterwards returns to the terrestrial mode. Similar to the previous solution, the fact that S-UMTS reception is independent of terrestrial coverage (S-UMTS uplink instead of T-UMTS uplink) means that the terminal can profit from the larger satellite coverage but in this case no satellite and terrestrial link can be set up simultaneously.

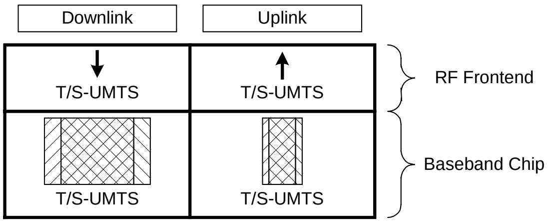


Figure 12: Optional configuration with reconfigurable receiver and transmitter architecture

6. CONCLUSIONS

The SATIN architecture and its relation to the geographical- and service-complement approach was explained. Possible issues related to the T & S-UMTS were identified and top-level solutions were outlined. Different services coexistence scenarios and customer types stemming from the service requirements were described. Possible terminal configurations were introduced and their cost and size were compared with the reference terminal (standard T-UMTS terminal).

REFERENCES

[1] B.G.Evans, M.Mazzella, et al; "Service scenarios and system architecture for satellite UMTS IP based network (SATIN)", AIAA ICSSC 2002 Motreal, Canada.

[2] T. Severijns, W. De Win, et al; "The intermediate module concept within the SATIN proposal for the S-UMTS air interface"; IST Mobile Summit 2002,Thessalonica, Greece.

[3] 3GPP TS 22.146; "Multimedia Broadcast/Multicast Service"; Stage 1; (Release 5)