SERVICE SCENARIOS AND SYSTEM ARCHITECTURE FOR SATELLITE UMTS IP BASED NETWORK (SATIN)

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ABSTRACT

This paper describes the services, market, business and architecture analysis done in the EU IST personal and mobile satellite project SATIN for S-UMTS. The service suitable for the S-UMTS is identified through market analysis and the profitability of the identified service is investigated through business analysis. Based on the profitable services and the intermediate module and terminal complexity and cost, the S-UMTS system architecture is selected. As part of the SATIN architecture scenario, the intermediate module concept is discussed as well.

INTRODUCTION

Success of GSM in earlier nineties in Europe brought the momentum in satellite industries for personal communication via satellite with the aim of providing GSM type of services outside the terrestrial GSM coverage. The assumption made at that time was that the GSM would take long time to deploy around the globe and the satellite could be deployed quickly and hence target the mass market. Based on that assumption, mobile satellite system (MSS) such as Iridium and Globalstar were developed with LEO satellites. The whole development period took approximately 5years. During that period the GSM spread into most of the populated area around the globe. This consecutive event left very little opportunity for MSS to grab the mass market and therefore the new MSS systems were forced to rely on traditional niche markets such as maritime and aviation for their revenue. This was too small as compared to the design & development and maintenance costs. The reality later forced the MSS systems to file the bankruptcy. This experience has shown the reality of the satellite industries position in the personal communication market and gave the clear indication that the technological success is not enough for a successful communication system and the proper market and business analysis are equally important in order to have overall success. This lesson forced the satellite industries to revise their strategies towards personal mobile communications.

Satellite UMTS IP based Network (SATIN) is one of the satellite projects formed in Europe to look into the above issues. The overall target of SATIN is to identify the service scenarios and propose more efficient system architectures based on IP, which suites the identified service scenarios for S-UMTS, considering the current and future prospective of the satellite systems.

SATIN was planned to proceed in four main steps: service scenario identification, overall system architecture selection, detailed definition of architecture components and validation of system performance through simulation. SATIN has already completed the first two set of tasks and it is currently in last two set of tasks.

This paper discusses about the SATIN services, business and architecture scenarios and the S-UMTS architecture selection procedure. Next section explains the service, market and business analysis done in SATIN and section 3 discusses about the issues related to system architecture and the architecture selection procedure. Last section draws the conclusions.

SERVICE, MARKET AND BUSINESS ASPECTS

Services and Market

Identification of the actual market potential and realistic market forecasts are indisputably the most significant aspects of any satellite venture. One of the principal questions traditionally posed for satellite systems is whether they should address a mass market, or target specific niche markets; an issue closely related to satellite systems positioning, with respect to terrestrial systems providing a similar set of services.

The whole market to be potentially addressed by S-UMTS may be divided into mass / consumer and the niche markets. The main characteristics of the latter are their limited size or/and the interest in a specific subset of the potential S-UMTS services. There are currently mobile satellite systems who make significant profits from these niche markets, the major ones being INMARSAT, OMNITRACKS and its European analogue EUTELTRACKS. An S-UMTS system would have to compete with these systems if it wanted to enter these niche markets, whose size is currently estimated at 500.000 users. It was clearly shown that a viable business case is not feasible if only the niche market is addressed.

One of the main outcomes from the S-PCN venture was that satellite systems could not penetrate the mass market as stand-alone systems. Integration and co-operation with the terrestrial system is necessary; in other words (and this seems to be the favourite term within satellite industry) satellite systems must stand **complementary** to the terrestrial systems. The level of complementariness though may vary; from a services point of view SATIN identified two main roles for the S-UMTS with regard to its terrestrial analogue:

The first -characterized as *geographical complement*- implies that S-UMTS offers the same set of services, that are provided by T-UMTS, to its users. It is possible to divide the geographical territories 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. 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.

The second –called *service complement* or *close co-operative*- suggests that S-UMTS should not attempt to offer voice or interactive services, where it has a disadvantage compared to the terrestrial networks. It should rather focus on the provision of multicast and broadcast services since it has the potential to provide these services in the most cost-efficient manner. 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. Moreover satellite systems provide capabilities that can be used in creating new services. For instance, satellite ground-location ability such as fleet management, route guidance, etc enables the development of aeronautical or maritime services (including information broadcast / multicast and various supplementary services). This is the reason why major niche markets, should not be neglected; Nevertheless it is the multicast/broadcast market that bears the potential to become the mass market for satellite. In this context, integration with T-UMTS is maximised and benefits arise, for the end-users, enjoying innovating services at a low cost, as well as for the operators of both networks (T-UMTS, S-UMTS) in terms of shared infrastructure investment. The in-car multimedia services are seen to be a significant market in the future and a main step towards convergence of broadcast and mobile systems.

After defining the scope of the S-UMTS with respect to T-UMTS, three different hypotheses are identified (“average”, “pessimistic”, “optimistic”) regarding the forecasted positioning of S-UMTS in the future integrated 3G landscape. Hypotheses indicate that the possibility for a mass market for S-UMTS in the medium/longer term cannot not underestimated, however, industry should be able to move beyond average projections and investors in S-UMTS should certainly adopt a mass-market approach i.e. a close cooperative to gradually create such a mass market. Consequently, the service portfolio of S-UMTS should be built around multimedia Multi/Broadcast services, without excluding any other types (to meet requirements from certain niche markets, that may assure an initial customer base during the first period of system deployment). The possible markets addressed by the satellite systems are analysed subsequently comprising both traditional (e.g. Maritime, Aviation) and emerging satellite mobile markets. The analysis concludes into a market proposition for S-UMTS, indicating a set of market / service combinations that seem to fulfil the most crucial requirements.

A grouping was introduced for services of the proposed S-UMTS portfolio, according to which certain services that are considered essential for the portfolio (in terms of comprising the basic functionality offered to the users) were characterised as “core” services. It should be mentioned that the interpretation of a service as “core” or not, depends on the actual significance of the service’s role in the rationale of each service delivery scenario, thus the same service may have different interpretations in different T/S-UMTS integration & service delivery scenarios.

The following notations were used for characterising the services:

⦿ Indicates a "**core**" service of the portfolio with a possibility to be delivered in indoor as well as in outdoor environments.

○ Indicates a "**core**" service of the portfolio with a possibility to be delivered outdoors.

◈ Indicates a service that might be included in the portfolio to serve needs of addressable markets with a possibility to be delivered in indoor as well as in outdoor environments.

◇ Indicates a service that might be included in the portfolio, with a possibility to be delivered outdoors, to serve needs of the addressable markets.

Considering all the above, and by maintaining only the core services for the promoted "close co-operative" the SATIN service portfolio is given in Table 1.

Table 1: SATIN Service Portfolio

S-UMTS vs T-UMTS approach	S-UMTS in a close-cooperative /service Complement	
S-UMTS service scenario	Indirect	Direct
Conversational services		
Emergency (voice) call	⦿	○
Messaging services		
Emergency message	⦿	○
Retrieval services		
Basic Internet access	⦿	○
Basic Intranet/ extranet connect	⦿	○
Enhanced Internet access	⦿	◇
Enhanced Intranet/ extranet connect	⦿	◇
Location based data retrieval	⦿	○
Distribution services without user control		
Video On Demand	⦿	○
Audio Broadcast	⦿	○
Distribution services with user control		
Location based broadcast	⦿	○
Content delivery	⦿	○

Business case

A Business Case was built for the various combinations of service / market scenarios, conducting a sensitivity analysis to indicate the conditions (number / type of users, way of using the system, average revenue per user) that may guarantee the financial viability (positive NPVs) of an S-UMTS system venture, and extract conclusions on the potential mix of services and T/S-UMTS synergy approach required to attract the volume of users that are essential for a viable investment.

SATIN make an (as realistic as possible) hypothesis regarding the overall deployment cost (including pre-operational and operational phase) and annual operating cost of the system. SATIN make appropriate assumptions on the prospective number of users for S-UMTS, on the basis of forecasts from existing studies ([1][2][3]) and the afore-mentioned hypotheses. SATIN examined various scenarios for revenue / cost of revenue based on assumptions for the ARPU considering forecasts used in ([2][3]). For calculating the average cost of revenue per subscriber SATIN make a realistic hypothesis on how the anticipated ARPU was split between the S-UMTS operator (e.g the part responsible for the S-UMTS space segment and gateways) and the operators value chain partners (e.g. terrestrial mobile/ fixed operators & services providers/ roaming partners). For the sake of the financial analysis SATIN categorizes S-UMTS potential users into 3 groups as shown in Figure 1 ("Direct", "Roamers", "B-M users") and the estimated number of users for each case based on the there hypotheses in given in Table 2.

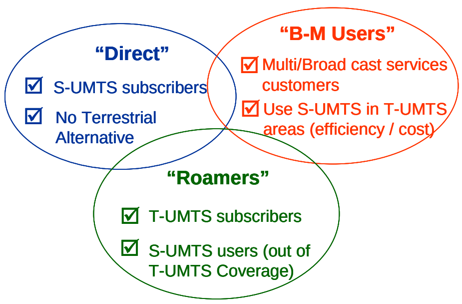


Figure 1: S-UMTS User categorisation in the SATIN Business case

Table 2: Prediction of number of users for S-UMTS considering three different hypotheses

	1st Oper. year	**6th Oper. year**
"Direct"	**20 – 50k**	**0.2 – 0.5M**
"Roamers"	**1.06 – 2M**	**1.84 – 3.5M**
"B-M"	**0.7 – 1.6M**	**2 – 2.8M**

An overview of the S-UMTS system cost is provided, where SATIN also mention relevant assumptions made in ([2][3]). It is based on a GEO constellation with global coverage comprising 5 (+2 spare) GEO satellites of 15 years life expectancy and up to 20 gateways. An estimation of the anticipated operating costs per annum for the S-UMTS organization (assuming a co-operative approach for S-UMTS & T-UMTS) is also provided. The expected financial performance of the investment project is analysed for various scenarios, indicating expected NPV, profitability (net margin) (Figure 2) and break-even point/gross earning expectations (Figure 3) from scenarios producing positive cash flows. From the analysis, the following conclusions were made:

- A global S-UMTS project is not viable if we assume a user population that comprises only of direct users. Their numbers are simply not sufficient to support the investment.

Scenario ID	Users 1st op. Y (K)	Users 6th op. Y (K)
Only_B-Musers_AVE	1.15	2.4
Only_B-Musers_OPT	1.6	2.8
Only_Roamers_OPT	2	3.5
AVE	2.72	5.42
OPT	3.7	6.9

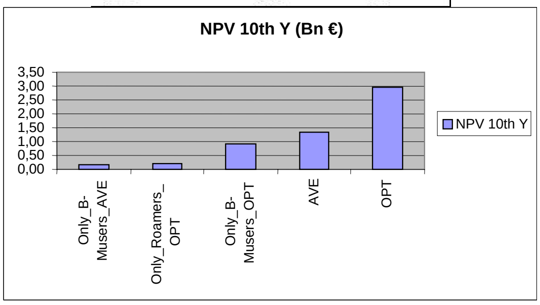


Figure 2: Scenarios producing positive cash flows

Scenario ID	Users 1st op. Y (K)	Users 6th op. Y (K)
Only_B-Musers_AVE	1.15	2.4
Only_B-Musers_OPT	1.6	2.8
PESS	1.78	4.04
Only_Roamers_OPT	2	3.5
AVE	2.72	5.42
OPT	3.65	6.8

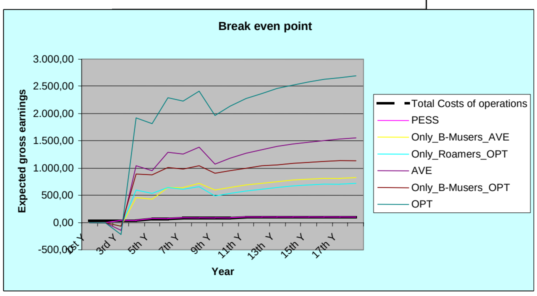


Figure 3: Break-even and Project gross earnings

- An approach which will only focus on the needs of roamers can produce financially healthy results if the system operator will succeed to attract, from the very beginning, a number of users that will exceed 2 millions, which is highly unlikely, keeping in mind market forecasts assessment. One should also note that in the case where the portfolio of services will include broadcast/multicast services the investment could be viable if the operator will succeed to attract a number of users in the area of 1.15 million willing to use them. This appears to be possible and easier to be achieved, keeping in mind that the users defined as B-M users are normally users in the urban, suburban areas that will seek to S-UMTS a cost efficient alternative for T-UMTS services.

- The analysis further suggests that in order to achieve high profitability the S-UMTS should address a mixed population of users with varying needs. B-M type of services should be the basis for the services portfolio to minimise potential implications due to spectrum and secure higher ARPUs.

- All the scenarios with the potential to produce positive financial results assume a considerable population of users (in the order of millions and not thousands) from the very beginning of commercial operation. This imposes a very close co-operative approach for the system deployment with the terrestrial cellular operators to make sure that the initial user population of S-UMTS will be sought among their home (numerous) users and not the occasional roamers.

SYSTEM ARCHITECTURE FOR S-UMTS

Different architecture scenarios, their service related advantages & disadvantages are described in this section. Methodology adapted for the architecture selection is also discussed.

S-UMTS Reference Architectures

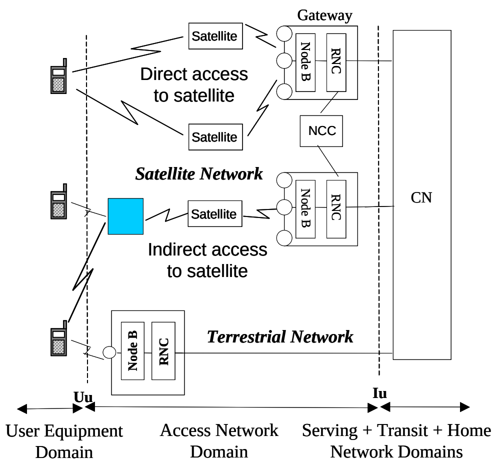


Figure 4: Reference architectures for S-UMTS

The Figure 4 shows the possible S-UMTS architecture scenarios and their elements. The elements, *Radio Network Controller (RNC), Node B, Radio Network Subsystem (RNS), Iu interface, Uu interface* are same as with T-UMTS and the elements specific to the satellite systems are *network control centre (NCC)* and *fixed earth station (FES)/Gateway(GW).* Architecture scenarios shown in Figure 4 is based on the *coverage oriented* and *broadcast oriented architectures* concept and they are explained below.

Coverage oriented

There are two ways to provide coverage, either through a direct link between the MT and the satellite or indirectly using intermediate equipment called intermediate module repeater (IMR) or Gap filler. This categorization is also applicable to broadcast oriented scenario as well.

Direct configuration

The services supported are basically the same as those provided by the T-UMTS. Due to link budget constrains, operation in indoor conditions is limited. Therefore additional techniques need to be adapted to cover this case. The cost for the usage of the S-UMTS will remain higher than that of T-UMTS. Consequently, all satellite terminals will additionally support T-UMTS as well. Whenever the T-UMTS becomes available, the bi-mode terminal will restore to terrestrial mode.

Indirect configuration

Here satellite systems are expected to support any MT compatible to the T-UMTS without modification. This requires insertion of an IMR between the MT and the satellite. This module adapts the satellite signals to the MT interfaces and inversely and enables full independence from the terminal segment. The satellite component ensures traffic transportation between local networks and the public network. This has several advantages:

- Reduced investment and delay in the development due to a possible reduction in complexity/constraints on the terminal design since the system is compatibility with existing terminals, and thus enabling early introduction of service.
- To benefit from satellite services, the user does not have to learn the usage of another terminal with a different man machine interface. His environment is not affected. This will become increasingly important since the number of features in a terminal will grow.
- The subscribers is only faced with small additional fee for the satellite delivered services
- The S-UMTS may be improved and optimised for capacity as well as bandwidth performance provided that the booster accommodate with new features or S-UMTS evolutions.

Two system configurations may then be envisaged, collective and individual. A system supporting both can also be envisaged.

Collective configuration: The satellite-based system is inserted within a radio access network of the T-UMTS. The system is used in a trunking mode and transports the traffic exchanged between the terrestrial network and the local network. The intermediate module constitutes an entry point for a local network. It consists of a part of the radio access network or of a single BS. It provides UMTS services to all terminals within the coverage area. Rapid installation of the IMR could be an advantageous feature. Installation on a building roof or terrestrial mast for earth fixed coverage, on board a vehicle transporting passengers as well as maritime and aeronautical applications can be foreseen.

Individual configuration: The approach is similar to the direct access to satellite system except that it is based on a distributed terminal concept (MS: Mobile Station). It consists in a booster-equipment and a standard terrestrial terminal. The booster converts the satellite signals into a format compatible to the short-range wireless interface of the terrestrial terminal. It relies on the assumption, that mobile stations will support such short-range wireless interface to connect phone accessories as well as computing devices.

To reach the largest market, different kinds of booster may be envisaged according to:

Mobility capability criteria: The transportable or nomadic types, bigger in size but can be installed in a vehicle or easily carried out in a suitcase.

Service capability criteria: Voice and low rate data only, Video, voice and high data rate, Traffic asymmetry for video, voice, high data rate on downlink and voice, low data rate on uplink.

Basically such systems can address nearly the same market as the "Direct access to satellite" configuration since most of the market segment identified can be targeted with a terminal in a distributed configuration (several parts). In most cases, a nomadic terminal is able to satisfy the needs of the users. It can either be a transportable terminal or a terminal installed on-board a vehicle.

Broadcast oriented

The S-UMTS is based on similar transport capabilities provided by the DAB and/or DVB technology. The end user benefits from T-UMTS services and can simultaneously access services offered by the S-UMTS terminal configurations in two modes indirect and direct configuration mentioned in the coverage oriented case.

Intermediate Module Repeater (IMR)

Broadcast and multicast are considered as promising candidates for S-UMTS services and the mass market for them is in and around build up areas (urban areas). But the direct configuration shown in Figure 4 are not suitable for urban areas due to the following reasons:

- There is no direct satellite reception inside the build up area because of the high blockage.
- Users are used to use mobiles inside buildings.

Hence it is considered that a intermediate module repeater (IMR)/gap filler is the better solution to solve the problem of urban area satellite coverage. The IMR acts as a repeater in both way or in one way depending on the services. Since voice is not considered here, the services are mainly asymmetric.

When the design of IMR and the definition of the interfaces between satellite-IMR and IMR-terminal are investigated, the following points should be taken into consideration.

- Multicast and broadcast services can be well served by satellite
- It is anticipated that satellite would be cheap for international roaming compare to terrestrial systems.
- Terminal complexity should not increase significantly due to the introduction of the intermediate module.
- A big constraint experienced by the terrestrial system was placing the base stations in a cost effective and environment-friendly way. Therefore the satellite industry may also experience the same problem in installing the intermediate modules.

The nature and the position of the IMR will be further investigated in SATIN project.

IMR Environmental Scenarios

This section explains possible *IMR* scenarios, which can target the mass market and type of services each scenarios aiming for. The following issues may be different for different scenarios or may be same.

- *IMR* functions (e.g. just like a booster)
- Interfaces *SAT-IMR* and *IMR-SMT*.

Urban and Suburban environment

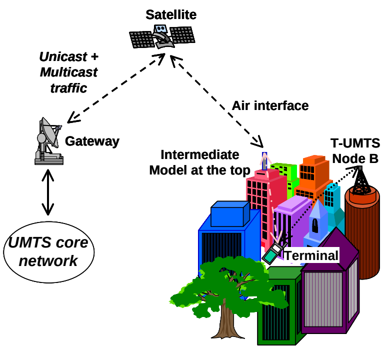


Figure 5: IMR in urban environment

Figure 5 shows the arrangement of an *IMR* capable of satellite reception inside the build up area and inside the buildings. There are two possible service scenarios, only broadcast and multicast services via satellite to the local users and full services via satellite to international roamers. However the *IMR* may also be just a repeater without incorporating any functions of *RNC* or *Node B*.

Vehicular or Highway Environment

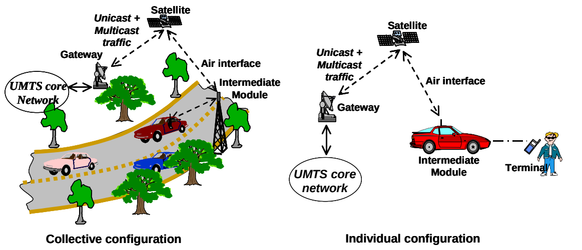


Figure 6: Vehicular or Highway Environment

IMR positions for the in-car application and the respective configurations have been shown in Figure 6. The *IMR* can be just a repeater and hence the terminal use the satellite mode or the *IMR* can translate the signal into terrestrial form so that the terminal can use the terrestrial mode.

Ship, plane and UMTS islands case

In this scenario (except UMTS islands), the *IMR* may feature *Node B* or simple repeater functionality. In the UMTS island case the satellite link represents the interface between the *UTRAN* and the *CN* (*Iu*).

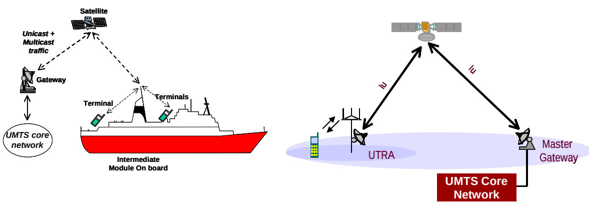
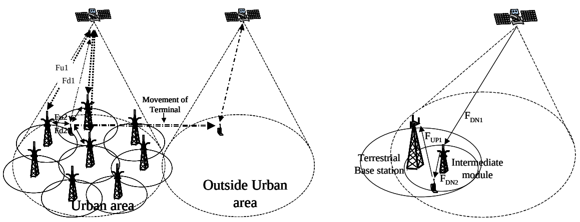


Figure 7: Remote environment (Ship, Plane and UMTS islands)

IMR possible Functionalities

As discussed in the previous section, the IMR can be a simple repeater (Booster) or Node B or RNC and Node B. This section only investigates the simple repeater case (which is most possible case for the broadcast and multicast case and also less complex and cost effective). For other cases refer [5]



Type I: Two way repeater *Type II: One way repeater*

Figure 8: Simple repeater case

Simple repeater case, the IMR receives the signal in the S-UMTS band from the satellite, amplifies and retransmits it towards the terminal. Similarly, it receives the signal from terminals and transmits it towards the satellite. The same frequency band may be used for both links, namely the SAT-IMR link and the IMR-MT. Alternatively different bands may be used for each link, in the latter case the IMR features frequency conversion capability. Therefore the terminal can receive the same signal from two or more IMRs as shown in Figure 9 similar to multipath propagation. When the terminal moves out of coverage of the IMR, it can directly communicate with the satellite since the signal attenuation is very low outside the build up area. Hence the S-UMTS mode can be used at the terminal inside and outside the build up areas.

Contrary to the terrestrial case where the signal received from other cells is considered as interference, the signals transmitted by other IMRs can be considered as multipath signals except for the case that the IMRs are located in different spotbeam coverage area. Here a trade-off exists between IMR system cost and terminal complexity.

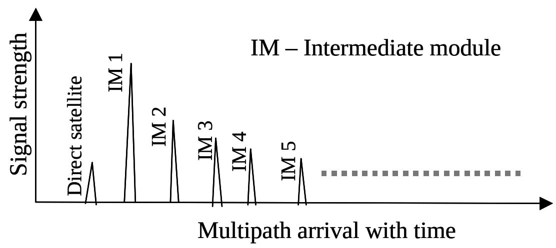


Figure 9: Same signal through different IMRs

The multipath arrival delays of signals coming from different IMRs will mostly be larger than the arrival delays of the multipaths caused by reflections etc. of the signal coming from the IMR closest to the terminal. Extending the *RAKE* search window (larger delay line) implies on one hand a more costly terminal, but on the other hand a similar amount of signal code power can be received with lower power IMRs or less dense distributed IMRs.

Two types of repeaters are considered based on the SATIN architecture concept: bi-directional (Figure 10) and unidirectional (Figure 11) simple repeaters.

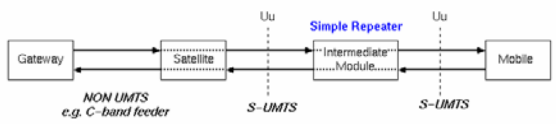


Figure 10: Bi-directional simple repeater

In bi-directional case, both downlink and uplink will use *S-UMTS* frequency bands. Positive aspects of this approach include:

- Creation of a multipath environment; a RAKE receiver in the terminal can exploit this and enhance the *SNIR* of the signal. Note that this is limited to urban areas, in rural environments the channel still has a Rice/LOS character.
- Effectively 'everywhere/ anytime' coverage, because the terminal can communicate pseudo-directly to a satellite in an urban environment and directly in an open environment.

Negative aspects include:

- Only slow inner loop power control (PC) is possible due to large propagation delay between the IMR and the satellite. PCC instructions will be given on a frame-to-frame basis (100 Hz instead of 1500 Hz as in T-UMTS). This will result in a serious decrease in the ability to compensate for fading channels.
- No possibility to implement any form of *PC*, to regulate the transmit level of the *IMR*s to mitigate intra-spotbeam interference.
- Terminals will have to be dual-mode for both the Tx and Rx chains, and hence more expensive.

Terminal considerations:

It seems difficult to design low cost *power effective handheld* terminals that can handle the full rate uplink straight to the satellite, as is the case in rural areas not covered by the IMRs. This does not necessarily mean that receive only scenario is the only option left. For low data rates the processing gain can be high enough to boost the uplink signal sufficiently at the satellite receiver. Hence an asymmetrical link scenario (Multicast/Broadcast) seems feasible for handheld terminals.

When aiming at the geographical complement goal of *S-UMTS*, handheld terminals will only be able to provide *low uplink bit rates*. A possible way to alter the uplink bit rate is to use an extension module with enough transmit power connected to the terminal (or laptop/PDA/etc.) with a short range wireless link or a cable or to use the nomadic terminal. The highest performance will probably be reached when using a vehicular IMR that can either be a simple repeater, or a short range wireless interface/*S-UMTS* converter, because in this case available Tx power will be highest.

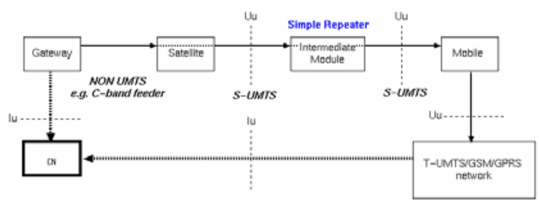


Figure 11: Unidirectional simple repeater

The unidirectional case has the following advantages compared to the bi-directional case:

- The IMR complexity (and cost) will be greatly reduced, because the *RF* front-end must only be capable of receiving from satellite and transmitting to the mobiles.

- The terminal complexity (and cost) can be made considerably lower because it must only be able to receive S-UMTS. The most cost-saving factor in that case is the considerably reduced complexity of the RF/IF part. Power consumption will be considerably less since no S-UMTS Tx in terminal.
- Benefit from the terrestrial uplink infrastructure features, like (fast) uplink PC, RAKE combining (T-UMTS), is feasible.

Negative aspects are:

- If T-UMTS is selected for the uplink, the geographical complement concept is violated; it is made clear though in [1] that SATIN adopts the service complement approach rather than the traditional, geographical complement one. If the up-link is GSM/GPRS the geographical complement goal is in a way achieved, since not many areas are outside *GSM/GPRS* coverage, but the up-link capabilities will of course be insufficient to support *full* T-UMTS services.
- T-UMTS/GSM/GPRS up-link gets some additional loading. This should however be very limited, since the targeted set of services are broadcast/ multicast.

This scenario seems to be the most interesting when geographical complement is not the main objective. However different types of terminals (in terms of T/S-UMTS capabilities) will probably be available in the market and customers need to pay more to get terminals with uplink S-UMTS capabilities (low rate).

Terminal characteristics and operational capabilities

Terminal characteristics

Terminals for wireless communication networks are characterised by different aspects. Perhaps the most obvious one is the supported radio transmission technology. Other main aspects are transportability, mobility and communication capability. In the following, the impact of each aspect on terminal complexity, cost and business opportunities is evaluated in more detail. Considerations are made more specifically for the S-UMTS terminal alternatives and two high-level terminal configurations driving the SATIN architecture definition, called *baseline* and *optional* in the rest of the document, are presented.

Terminal cost

From the future UMTS-user point of view, when UMTS becomes a commercial success, the price of the services and equipment (terminal) will be in line with the actual GSM terminal price. A slight increase of the general retail price is acceptable (up to 30%), but the market will not accept terminals having a retail price of more then 1,000 Euro. To make a comparison, current GPRS terminals of 450 Euro are considered as expensive. However prices are expected to drop. In Japan, who was the first to have a terrestrial UMTS network ready at the first of October 2001, terminals are sold for 400 up to 550 Euro.

Two aspects dictate the cost of a terminal. The first one is related to the production cost of such a terminal. The Bill Of Material (BOM) including all the requested hardware, the plastic and production cost must be kept as low as possible. In other words, the increase of the BOM due to the additional satellite capabilities of a terminal must be limited.

The second aspect related to the cost of the terminal is the development effort. Knowing that the development of a T-UMTS terminal is already a big effort, implementing the S-UMTS capability in a terminal should not have a major impact on the development effort and development time. Assuming the S-UMTS standard will be designed to have a maximum resemblance to the T-UMTS standard.

As third generation terminals will be devices with highly advanced functionality, product differentiation will be a successful method to attract the mass market with low-cost implementations on one hand and high-end professional equipment for smaller user groups on the other hand. One way to obtain product differentiation is by offering terminals with different capabilities regarding the supported radio transmission technologies, data rates and satellite reception and/ or transmission capability.

Radio transmission technology

The supported radio transmission technology has mainly an influence on terminal complexity and even more on business opportunities. Both complexity and business opportunities will drive production costs. Most radio transmission technologies adopted for personal communication networks can be subdivided into first, second and third generation systems and into terrestrial and satellite systems.

Terminals for first generation networks were mainly built with analogue technology resulting in expensive, heavy and power hungry devices.

Second generation networks paved the way for true handheld terminals thanks to the immense progress of digital technology. Today, terminals for second-generation networks are relatively inexpensive and have created a worldwide business. GSM is the best example one can give to prove this.

Third generation networks are entering the stage of commercial introduction and target on enhanced multimedia services and worldwide coverage and roaming. Due to these high level capabilities new efficient radio transmission technologies are developed. Terminals will become much more complex and will interact in a different way with the user.

Satellite networks for personal communication are far less evolved than their terrestrial counterparts. Although digital technology enabled the deployment of handheld satellite terminals providing similar services as second-generation terrestrial networks, terminal complexity and cost prohibited the deployment of a mass market. As a result, today, the only successful networks are situated in the niche markets of high-end business users, fleet management and maritime and aerospace markets. This evolution is nevertheless not surprising as radio transmission technologies adopted for these satellite networks where not at all optimised for co-operation with the existing terrestrial networks. As a result, a user of both networks needs to buy two separate terminals. For the mentioned niche markets this is not a constraint but for the consumer market it is a serious drawback. Third generation networks can create new mass-market opportunities in the satellite domain if the selected radio transmission technology demonstrates a high convergence with the terrestrial counterpart.

Despite the initial wish among several standardisation organisations to create one worldwide standard for third generation wireless networks, political as well as technical reasons prohibited a global convergence. As the situation is today, terrestrial third generation networks will be based mainly on four different standards known as UTRA-FDD, UTRA-TDD, TD-SCDMA and CDMA2000. For the satellite component, standardisation is not yet finished although five proposals for candidate radio transmission technologies have been submitted to ITU by organisations from all around the world. These are known as SW-CDMA, SW-C/TDMA, SAT-CDMA, ICO-RTT and Horizons. In order to enable mass production of low-cost terminals and to guarantee global roaming, terminals will need the capability to support multiple modes including combined terrestrial-satellite capability.

Multi-standard terminals are already used for second generation networks like combined GSM/DECT, GSM/GPS and second-generation satellite terminals with additional GSM functionality. In most of the cases, these multi-standard terminals are nothing more than multiple terminals under one and the same cover, resulting in expensive devices, unattractive for a mass-market approach. For future terminals supporting operation in multiple third generation networks together with existing or enhanced second generation systems, operating in the terrestrial and/or satellite domain, new terminal architecture concepts are necessary. So-called ‘software defined radios’ will show very high flexibility enabling the support of different radio transmission technologies. It is obvious that the complexity of such multi-standard terminals is largely influenced by the convergence between the supported standards.

Flexible, reconfigurable, multi-standard terminals will bring new opportunities in several different ways. First of all, they enable real global roaming. Secondly, although multi-standard terminals will be high complex devices they could reduce production costs by offering a more differentiated product range based on one and the same hardware platform. Another less obvious advantage is the smoother evolution towards third generation by providing backwards compatibility with second-generation networks. And last but not least, bi-mode terrestrial/satellite terminals will create a critical mass for personal communication satellite networks by reusing the existing mass-market already created by the terrestrial component. However, in order to succeed, the satellite component has to provide more than just enhanced coverage; a real complementary set of services. Existing satellite networks are purely coverage focused thereby missing most of the mass-market consumers who will rather spend their money on new services than on a coverage extension. The best example proving this is the enormous spread Internet has made in the last couple of years using the existing telephone network infrastructure.

Terminal transportability

Terminal size will always be a trade-off between user-friendliness, battery autonomy and transportability. It says more about the way the user interacts with the terminal than how the user interacts with the environment. Wireless terminals for personal communication networks can roughly be divided into five different classes dependent on the required transportability:

- Pocket phone terminal type
- PDA terminal type
- Nomadic terminal type
- Modular built-in terminal type
- Plug-in terminal type

Architecture selection

The two architecture scenarios “base line” and “optional” selected on the basis of the earlier analysis on service, market, business, IMR and terminal complexity and cost, are depicted in Figure 12. A handheld mobile terminal, with one or both the options depicted in Figure 13, receives data through the satellite and/or the IMR, which features one-way, repeater functionality. The satellite path would be the preferred communication link, but if the user’s satellite path were blocked, the communication link would be sustained via the IMR stations. The return path is provided via the T-UMTS network (*baseline* case). Alternatively, the terminal may also support direct transmission to the satellite (*optional* case).

The baseline and optional modes of operation identified are exclusive. A terminal may be tailored to one scenario (primarily baseline) or possibly feature all capabilities, i.e. full dual/parallel mode capabilities.

Requirements related to the baseline scenario

The main requirements identified are:

- Dual/Paralle mode capabilities with S-UMTS Rx and T-UMTS Tx/Rx,
- T-UMTS paging capability whenever in satellite active reception or terrestrial idle mode, hence simultaneous Rx of T-UMTS and S-UMTS.
- Management of interruption/continuation of S-UMTS service versus T-UMTS service.
- Possible baseband combination of multipath signals from the satellite and the IMR.

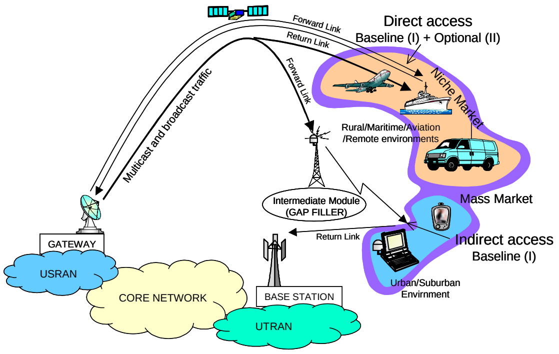


Figure 12: SATIN Reference Architecture

However the terminal capability may be restricted to S-UMTS Rx only for a given subset of services (pure broadcast, without need for interactive link).

Requirements related to the optional scenario

The main requirements identified are:

- S-UMTS Tx/Rx capabilities with low data rate return link, since out of T-UMTS coverage
- Possible baseband combination of multi-path signals received from the satellite and from the IMR.

Requirements related to the terminal architecture

The subsequent terminal architecture shall be designed for efficient dual/parallel mode capability, and should imply the minimum of development to support S-UMTS broadcast/multicast services. Relying on re-configurable hardware, one intends to use common processing means to perform baseband processing across the different modes. The terminal functional macro-architecture is illustrated in the Figure 13.

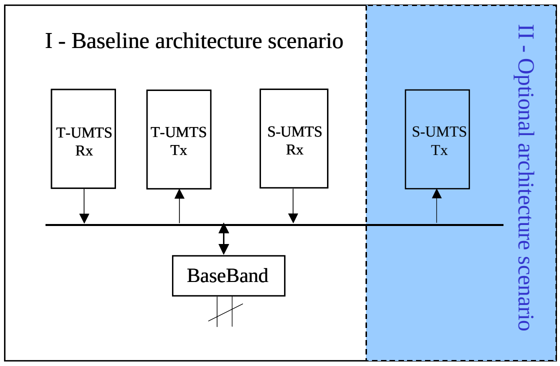


Figure 13: Terminal Architecture Scenarios

The number of active communication chains implemented in the terminal shall be reduced at the very minimum, i.e. reduced minimal additional components compared to the basic 3G terminal. One assumes that 3G terminals typically feature 2 Rake receivers to be assigned.

Path combination implies that the receiving chain is capable of processing the actual differential path delays. However path combination may not be effective, in which case the Rake receiver should provide sufficient agility to continuously search the path with maximum signal energy and to quickly set its fingers from one delay position to another. This subsequently requires a searching window size that covers the maximum differential delays that may occur between essential energy paths.

Actors role and Network functionality distribution

As already mentioned, the SATIN approach considers a "close co-operative" model between the Satellite infrastructure / services provider and the T-UMTS operator. The actual interpretation of the relation between the 3 entities (STUO, SGO and SSO) can be seen from either the end-user or the network point of view. From the end-user perspective, the differentiating factor is the ownership of the customer relation (CR). Here there is a number of different scenarios, most of which are independent of the underlying architecture.

From the network perspective variations would come from merging functionalities, i.e. allocating combinations of roles to actors. The relationship between the STUOs is usually the first one that comes into mind. The existence of two different operators, each one responsible for an individual access network, e.g TerraPHONE for the terrestrial component and SatPHONE for the satellite component in Figure 14, would necessitate that some state be kept at the interface of the two networks regarding the subscriber. In effect each operator would have to maintain his own database for registration and finally for accounting and billing purposes. The maintenance and exchange of this state would introduce the need for some additional signalling, whose simplicity would be lower bounded by the derivation of a couple of messages using the services (and eventually unused bits) of existent protocols and upper bounded by the definition of a new lighter or heavier interface, including the two (or more) databases and the CN nodes.

In SATIN we maintain the simpler scenario depicted in Figure 15, where the same (terrestrial) operator runs both the terrestrial and the satellite access networks. In this case there is one database set, calling for single registration, and the extra requirement is some extra state kept at the CN nodes so that the traffic can be routed correctly between the two RANs.

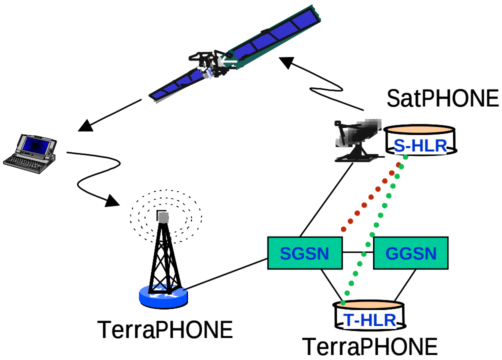


Figure 14: Scenario I – T & S-UMTS operators different

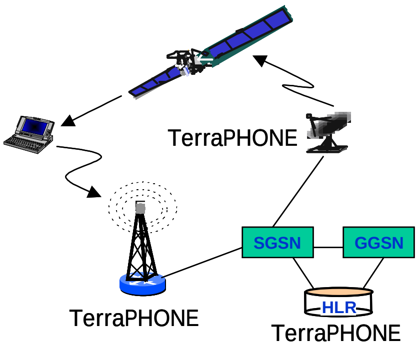


Figure 15: Scenario II – T & S-UMTS operators same

CONCLUSIONS

Services, market and business analysis have been done and it has been shown that multicast and broadcast services are most suitable candidate for the S-UMTS system. Niche market approach based on the satellite direct users only is not profitable at all and the mass market approach based on the roamers and broadcast and multicast users is the promising one in terms of profitability.

Different architecture scenarios under the categorization of “coverage” and “broadcast” oriented architecture and “direct” and “indirect” architecture, have been discussed and the broadcast indirect case has been considered as more suitable for the initial stage of S-UMTS deployment to target the mass market.

Future work will focus on the detail protocol definition of the individual system elements and the evaluation of their performance will be made via simulation.

REFERENCES

[1] “Structuring the service revenues opportunities”, Report No 9 from the UMTS Forum, September 2000.

[2] “Final report S-UMTS Preparation of next generation universal mobile satellite telecommunications systems”; ESTEC-13694/99/NL/US, ESA S-UMTS study, 29-11-2000

[3] “S-UMTS final report”; ALENIA Spazio, ESA contract 13695/99/NL/4S, 04-10-2000

[4] “Short overview on technical aspects of integration of terrestrial and satellite system”; extract from input of Telenor and Space Engineering to the ASMS-TF Commercial Requirements report, May 28 th 2001.

[5] Severijns T, et al; “ The intermediate module concept within the SATIN proposal for the S-UMTS air-interface”; submitted to IST Mobile Summit 2002.