# SATELLITE-UMTS IP-BASED NETWORK (SATIN)

**B.G.Evans, R.Tafazolli and K.Narenthiran**
Mobile Communications Research Group
Centre for Communication Systems Research
University of Surrey, Guildford GU2 7XH, UK
Tel: +44 (0)1483 879131, Fax: +44 (0)1483 876011
B.Evans@eim.surrey.ac.uk

## ABSTRACT

The EU-IST IP based satellite project, SATIN is presented in this paper. Role of satellite in 3G mobile communications systems is discussed based on success and failure of the first (1G) and second (2G) generation satellite systems. The significant of the SATIN project in terms of present and future market and technology trend is stressed. Objectives and the technical approaches of the project are outlined. Foreseen services from S-UMTS for 3G are discussed. Expected novel concepts from SATIN toward S-UMTS are explained. Impact of SATIN in mobile industry is also pointed out.

## 1. ROLE OF SATELLITE SYSTEMS IN 3G

In the past the satellite portion of UMTS (S-UMTS) has been developed in isolation from the terrestrial portion (T-UMTS). The latter is well developed and standards are agreed as part of the IMT-2000 finally. S-UMTS on the other hand has no international agreement and is in the stage of having several candidate submissions being considered standards bodies (3GPP, ETSI-TC-SES, ITU-WG). Until now the priority with the operators has been to roll-out the 3rd generation terrestrially and they have not seen a role for satellite and therefore have not been interested in pursuing its standardisation.

The situation has been exacerbated by the failure and delay of the 2G mobile global satellite systems (Iridium, Globalstar and ICO) that have all been developed in isolation and with proprietary standards. Where satellites have failed is when they have tried to compete head-on with terrestrial systems using services that the latter can better provide, both in economic terms and within the same time frame. In addition, satellite systems that try to satisfy the global market have evolved very expensive infrastructures (constellations of LEO/MEO involving 40-70 satellites (LEO) or 10-15 satellites (MEO) and complex ground segments). The demands of the financial markets have not been able to sustain such high up front costs together with a slowly evolving customer base due partly to the unforeseen and rapid expansion of terrestrial systems (GSM) service areas.

Mobile satellite systems with niche markets such as those proposed to be served by the super GEO's (ACeS, Thuraya, etc.) could still succeed. Such systems are only just coming into service and have the advantage of reduced terrestrial competition due to the difficulty of terrestrial roll-out in the areas covered (e.g. Asian regions) and lower initial costs due to the need of only a few GEO satellites. So the jury is out in this area.

Additionally of course INMARSAT have for more than thirty years sustained a very good business in providing mobile satellite services to maritime, aeronautical and latterly to land vehicles. INMARSAT's system is global using GEO satellites and has been built on the niche area of maritime (plus to a smaller extent aeronautical) in which there is little competition. It has not been a system in which "mobility" in the terrestrial mobile radio sense has been provided and in this respect it is different from the 2G SPCN's.

Conventionally satellites have succeeded where they have made use of their unique advantages:

- Quick to provide services (time niche)
- Broadcast (wide area) coverage
- To cover areas in which terrestrial infrastructure cannot economically provide the service
- To supplement terrestrial services

This leads us to the conclusion that we must consider satellite as part of an integrated UMTS service provision (e.g. T/S UMTS) and not as a stand-alone alternative. The rapid roll-out element may not

have previously been considered as pertinent for satellite in UMTS but we are now seeing a slowing down in terrestrial roll-out of 3G due to financial pressures (partly brought about by the high license costs) and availability of equipments. There is also the problem of satisfying the mobile-IP element of future service demands. To provide economically for such IP services will require widespread availability of IPv6 and this will cause an additional delay in future provisioning. The likely scenario is thus one of scattered UMTS islands is, rather than continuous and extensive terrestrial coverage, for may be the next five years. In this scenario, satellites do have a role to play in both the backbone core network and in the wireless access components to provide early entry to market of UMTS services. However this must be as an integrated component with T-UMTS. Therefore we feel that IP based satellite system integrated with T-UMTS has promising future and SATIN, the EU-IST project [1] will accelerate toward that target while focusing the role of satellite in 3G mobile systems and in particular in the European context providing a more complete definition of S-UMTS.

## 2. SATIN PROJECT OVERVIEW

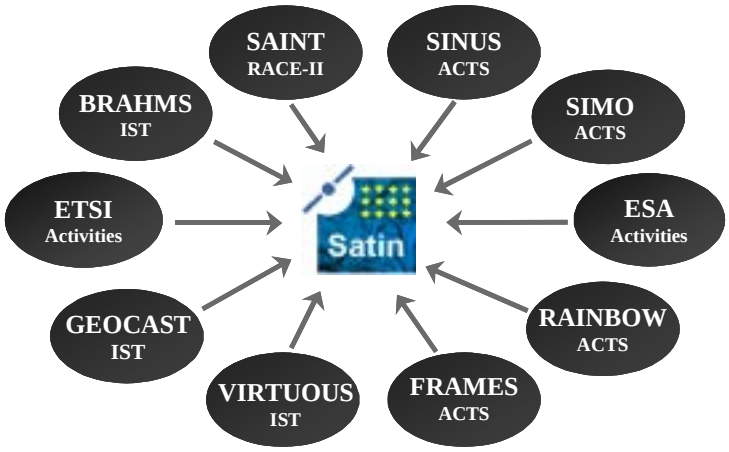


Figure 1 : Continuity and harmonisation of the S-UMTS research and development activities

Project SATIN is an in-depth research and technology project, which is harmonised with the S-UMTS research and development activities like SINUS [2], SUMO [3], RAINBOW [4], GEOCAST [5][6], VIRTUOUS [7] etc. It will define and evaluate efficient S-UMTS [8] access schemes (which will be based as much as possible on the UTRA access scheme to allow maximum commonality of terminals as shown in Figure 2.) based on packet-based protocols whilst allowing multicast service optimisation with the following objectives.

- To determine the potential role of satellites in UMTS and service delivery
- To define potential S-UMTS architectures to support the IP-based packet mode
- To suggest an optimised layer 1 & 2 design with reference to the IP-based packet mode
- To co-operate closely with other IST Projects and ESA R&D activities (Figure 1)
- To contribute to standardization efforts concerning IP/S-UMTS -in particular to the ETSI SES TC S-UMTS WG and 3GPP activities.

The following physical and functional entities based on the simple model in the Figure 2, will be considered in the overall packet based S-UMTS design in this project.

**Physical entities**

- Space segment and payload
- Terminal architecture and complexity
- Gateway (S-UMTS access network)

**Functional entities**

- Resource management
- Call/Connection control
- Mobility management
- IP QoS
- IP Multicast
- Physical layer implications

Different type of satellite constellation LEO, MEO and GEO and payloads, bent pipe and regenerative will be considered in the overall packet based S-UMTS space segment design. According to the

service requirements, one or combination of different space segment elements will be selected. For instance, different service types are associated with different levels of mobility: high data rate services will best suit multimedia-type terminals with low mobility and larger directional active or passive antennas, making a GEO-based solution more attractive. On the other hand, lower bit rate services are associated with mobile handheld type terminals requiring high satellite elevation angle statistics that can only be offered by a constellation of N-GSO based satellites. Protocol stack architectures of terminal, satellite and gateway will be investigated. Interfaces between, terminal and satellite, satellite and gateway and S-UMTS access network and UMTS core network will also be defined.

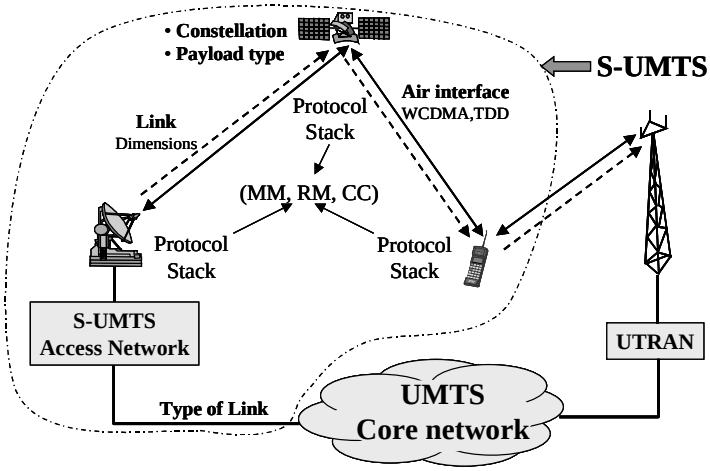


Figure 2 : Terrestrial and Satellite UMTS network architecture model

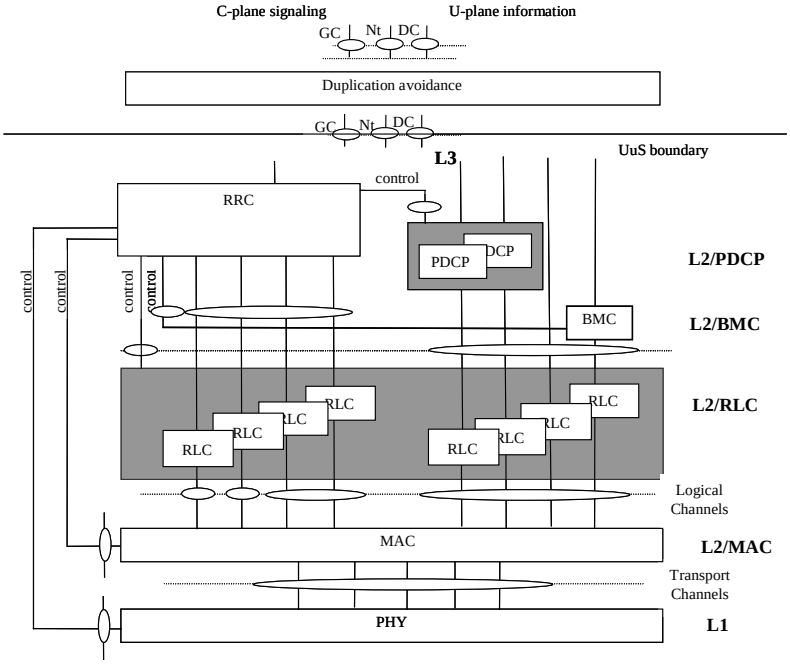


Figure 3 : Radio Interface protocol architecture (Service Access Points marked by circles)

These objectives target the whole of the "Access Stratum" of the UMTS, aimed at definition of a set of satellite-specific radio-technology dependent functions for the UMTS Access network. The higher layer "Non-Access Stratum" UMTS protocols will be adopted in order to ensure easy integration of S-UMTS with the UMTS core network, and with the T-UMTS. The definition of satellite packet data mode will lead to functional specification of the OSI physical layer (layer 1) and RLC/MAC layer (layer 2) protocols within the Access Stratum (see Figure 3).

Layer-1: Various aspects of the packet mode W-CDMA [9] access scheme need to be optimised in realistic satellite communication environments. Amongst these, fast acquisition, synchronisation, adaptive and predictive power control, and advanced receivers specifically designed for packet based communications are to be investigated.

Layer-2: Definition and optimisation of the MAC layer and resource management for the packet mode of S-UMTS need to be considered within the framework of this activity. Maximising the overall system capacity whilst achieving the required end-to-end QoS.

## 3. TECHNICAL APPROACH

The tasks within SATIN have been partitioned with information flow as shown in the Figure 2. The technical approach is divided into four main steps:

1. Definition of UMTS services and satellite system requirements,
2. Analysis of S-UMTS packet service requirements, definition of S-UMTS network architecture, and of resource management for efficient support of packet-based services.
3. Functional specification of S-UMTS packet mode access scheme.
4. Simulation, optimisation and evaluation of S-UMTS packet mode system elements.

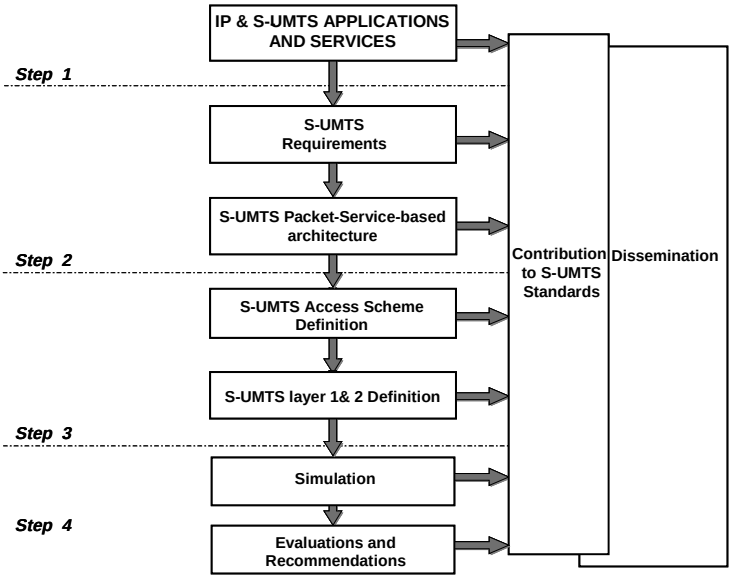


Figure 4 : Technical approach

In step 1 (Figure 4) the expected IP based UMTS services will be identified online with the standardisation bodies and other UMTS projects. Role and relative position of IP based S-UMTS with respect to T-UMTS will be investigated. Finally the services, which are more suitable with respect to economical and technical aspects, will be selected for further investigation in other stages. The proportion of each type of services in IP S-UMTS system will be evaluated since we believe that the satellite should have flexible platform to accommodate mixed type of service like the following examples.

a. Fixed type of services
   - Broadcasting
   - Act as backbone network to connect UMTS islands etc.

b. Mobile type of services,
   multicast, unicast to :
   - Pedestrian oriented services
   - Vehicle (car, bus, train, ship, plane etc.) oriented services

The output from this stage will flow into step 2 where we will evaluate the bandwidth requirements and dispersements with a view to the nature of the services e.g. asymmetric as well as symmetric and mixed mode satellite/terrestrial. Therefore this step is considered as very crucial for rest of the project.

In step 2, based on the services from step 1, IP based S-UMTS architecture will be proposed considering the issues such as IP multicasting, routing (as a function of the scenario e.g. satellite alone or hybrid satellite/terrestrial), IP mobility management, resources management and physical layer implications (Coding, modulation, power control, synchronisation). This work will be based on that already undertaken for terrestrial systems using unidirectional link routing (UDLR) schemes that in 3GPP.

In step 3 the satellite access scheme will be investigated and layer 1 & 2 defined. The access scheme will be dynamic and accommodate real-time variations of the traffic load across the various traffic classes. Again similar work for the terrestrial UMTS system, has taken place in 3GPP and the approach will be to maximise commonality between the satellite and terrestrial schemes. Scenarios contemplated will be GEO, non-GEO, OBP, non-OBP and a decision will be taken during the project to focus on one of these.

Step 4 will include more detailed simulations of aspects of the layer 1 & 2 definitions in order to optimise them in an integrated scenario with the terrestrial system. Recommendation at this stage of the project will be made to standards bodies etc. We will also attempt to identify how the considered functional architecture can be applied to the evaluation of a real 2G satellite system (e.g. Globalstar), thus proposing an example migration strategy towards a packet based S-UMTS (3G) system.

Based on the access schemes defined, a range of S-UMTS architectural issues will be extensively simulated resulting in performance analysis and evaluation under a wide range of operational conditions, and finally in specification of recommended solutions. Performance of the satellite "packet mode" will be evaluated using a combination of simulation and analysis at both system and link levels. The performance of the proposed techniques will be evaluated against a series of criteria, such as, Packet Error Rate, effective service delivery rates in different environments, spectrum efficiency, power control error, acquisition time and synchronisation accuracy, etc. The performance simulation will be used to show whether the proposed solutions meets the satellite system requirements set out.

## 4. MAIN THEME OF SATIN

The growth of the IP market in terms of services and applications (E-mail, Web browsing, teleconference, e-commerce, location based services) is supported by an exponential demand for IP solutions from the user side. S-UMTS is required to provide economical delivery of a wide range of IP-based multimedia services of up to 2Mbps and beyond, under a challenging propagation environment and a limited link margin to a range of practical terminals whilst maintaining full compatibility with the UMTS core network is fundamental. Achieving all the above is in fact one of the most challenging tasks ever undertaken by the mobile and satellite communication industry and would require innovative solutions and techniques. SATIN takes the lead to investigate and will propose innovative aspects as follows.

- New satellite UMTS access network architectures with emphasis on point-to-point multipoint service provision.
- Efficient IP access for multimode (T/S-UMTS) mobile terminals.
- Novel transport and access mechanism for guaranteed IP QoS.
- Bandwidth on Demand (BoD) for optimising radio resources.

SATIN will consider an innovative hybrid terrestrial-satellite UMTS service delivery where a number of scenarios will be investigated. In the first scenario (Figure 5), the satellite component is used for delivery of a range of broadcast and IP-based multicast services, such as electronic newspaper, live TV feeds, live stock exchange data, up-to-date weather news, fleet management, location dependent applications and a whole host of other services. This will allow efficient delivery of such services to a wide range of subscribers through a single satellite multicast traffic channel.

It is also known that the terrestrial component of the UMTS would not be able to accommodate a large number of high data rate users in a given cell. In the second scenario (Figure 6), delivery of asymmetric interactive broadcast and multicast services could be arranged so that the terrestrial network would be used as the up-link access network and the satellite component as the down-link.

This will allow much better utilisation of the scarce terrestrial radio resources particularly in areas with good S-UMTS reception.

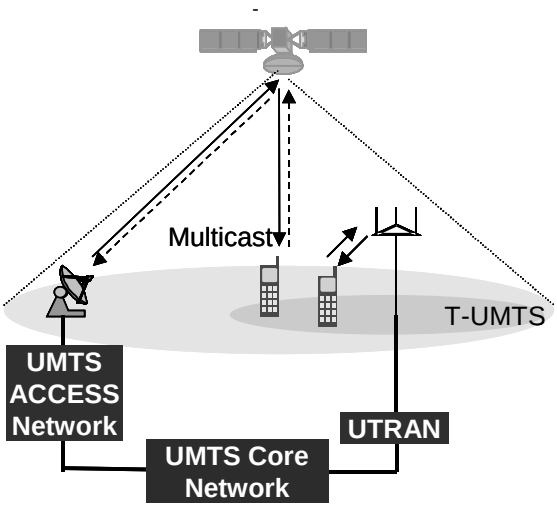


Figure 5 : Multicast service provision via satellite component of the UMTS

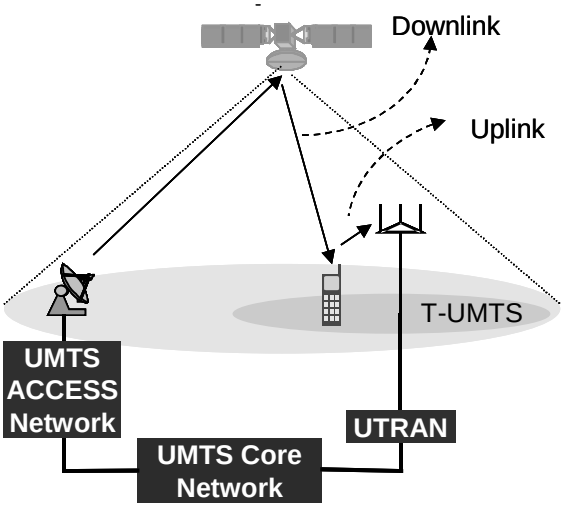


Figure 6 : Hybrid terrestrial-satellite UMTS up and down-link for delivery of asymmetric services

Satellite UMTS could also provide the link between the UTRA and the core network as follows:

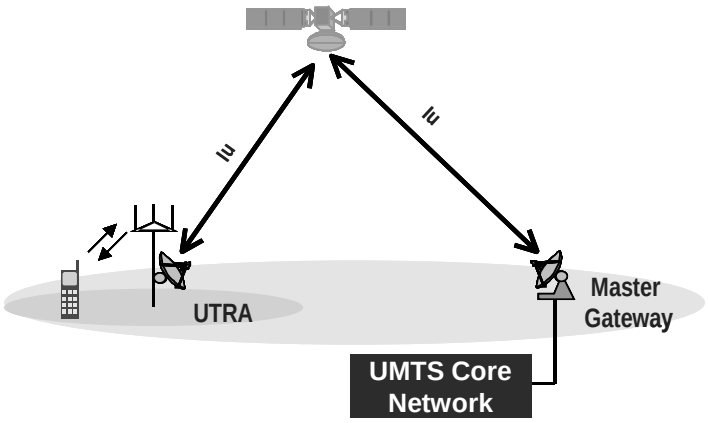


Figure 7 : Linking the access network to the core network

Several scenarios in which such a configuration could be extremely beneficial, can be envisaged:

- In one scenario temporary (transportable) terrestrial base stations can be placed to cover exhibition areas, or areas where a large population of potential users may gather for a temporary event. The link between the radio network controller (RNC) and the UMTS core network could be established via the S-UMTS access network.
- In another scenario, local UTRAN which are not connected to the global core network can be temporarily connected if demand for certain types of services are not expected to be high enough for permanent connections.

In doing so, a range of innovative techniques and technologies would have to be considered amongst which the following are a few:

- Optimisation of data link layer protocols such as ARQ, dynamic resource management, call admission control and advanced interference management scheme particularly for multiple operator scenarios.
- Packet based protocols for multicast S-UMTS and hybrid T/S-UMTS architectures.

- Adaptation and optimisation of the T-UMTS packet-mode specification to the satellite environment. Namely optimisation of various logical and physical channels such as the PCPCH (Physical Common Packet Channel), PDSCH (Physical Downlink Shared Channel), SCH (Synchronisation Channel). This will be based on use of a series of advanced physical layer techniques such as fast packet acquisition and synchronisation, receiver architecture based on Per Survivor Processing (PSP), predictive power control, adaptive coding, interleaving and modulation schemes together with blind sub-optimal interference mitigation techniques.

## 5. IMPACT OF SATIN

It is now realised that the availability of multimedia services such as web browsing, telemedicine services, distance education services, traffic monitoring, entertainment and broadcast services, e-commerce and banking, to the whole range of society is important to improve the quality of life, health, safety etc.. Even though these services can also be provided by UMTS terrestrially but they might prove very costly. Further it is well known that the provision of telecommunication services relates directly to the GDP and economic well-being of countries. Satellites are the way to ensure that these services are made available as early as possible to the society since S-UMTS could effectively act as the broadcast/multicast component of the UMTS. All of these services and more can be made available early in the 2000s via S-UMTS provided we can get an early standardisation and industrial intent in deployment of several systems.

Therefore we believe that IP based SATIN project will enable cost-effective delivery of a wide range of new multimedia and internet-based services to wide subscriber base within UMTS via proposing a effective and fully integrated satellite component for UMTS. Further the project is thus well aligned to EC telecommunication and space policies, is harmonising ESA and EU related R & D and is driving the European (as well as International) standards and regulatory bodies. It will place European Industry in a good position to exploit Satellite Mobile Multimedia both within Europe and world-wide.

## ACKNOWLEDGEMENTS

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