SATELLITE-UMTS IP-BASED NETWORK (SATIN)

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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 services and market forecast of the 3G mobile communication systems. Different S-UMTS architecture scenarios are presented and their characteristics are discussed. Selection of space segment and air-interface are also described.

I. Introduction

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.

Based on the success of traditional mobile satellite system (MSS) (INMARSAT etc.) and the failure of 2G MSS (Iridium, Globalstar, etc.), it is possible to conclude that conventionally the satellites have succeeded where they have made use of their unique advantages listed below.

- 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

Considering the above aspects and the concept that satellite is part of an integrated UMTS service provision and not a stand-alone alternative, the SATIN project tries to identify the services for S-UMTS and proposes IP based S-UMTS architecture.

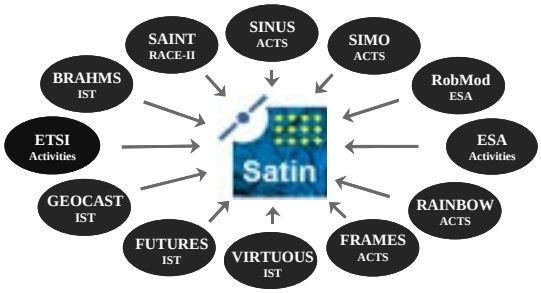

Figure 1: Continuity and harmonisation of the S-UMTS research and development activities

Project SATIN is an in-depth research and technology project, which is harmonised with the S-UMTS research and development activities like SINUS, SUMO, RAINBOW, GEOCAST, VIRTUOUS, FUTURE etc. It will define and evaluate efficient S-UMTS [ETSI00] access schemes (which will be based as much as possible on the UTRA access scheme to allow maximum commonality of terminals) based on packet-based protocols 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 (ETSI, 3GPP etc.) concerning IP/S-UMTS.

II. Services and market

From the 2G terrestrial and satellite system, it is obvious that the usage of satellite for voice applications is very small (30,000 users for Iridium and around 40,000 for Globalstar) compared to GSM. New predictions suggest that 200,000 subscribers is possible for S-UMTS as stand alone system. This figure is not enough to support a satellite business. Thus satellite community believes that the only way to target the mass market for S-UMTS is to goes for the cooperative services (broadcast and multicast) with other interactive services (like voice) through the terrestrial system. It is also important to mention here that the mass market is concentrated in and around build up areas. Hence satellite coverage must thus be augmented by terrestrial '*Gap fillers*' to retransmit the satellite signal to be received in urban areas and inside buildings.

III. S-UMTS architecture scenarios

The elements, *Radio Network Controller (RNC), Node B, Radio Network Subsystem (RNS), Iu interface, Uu interface* from 3GPP specifications and the elements specific to the satellite systems, *network control centre (NCC)* and *fixed earth station (FES)* are used in this paper to define different system architectures for S-UMTS under two main categories; *coverage oriented* and *broadcast oriented*.

III.I 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.

III.I.I Direct access to satellite 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.

III.I.II Indirect access to satellite configuration

Here satellite systems are expected to support any MT compatible to the T-UMTS without modification. This requires insertion of an intermediate module 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.

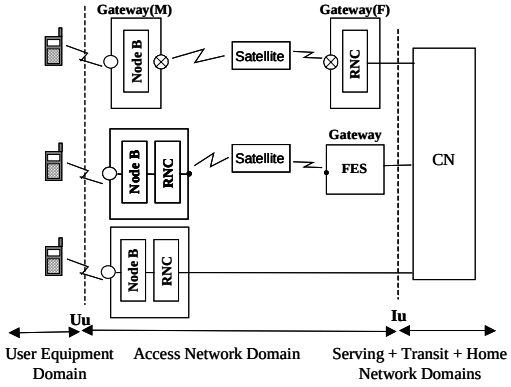

Figure 2: Collective configuration

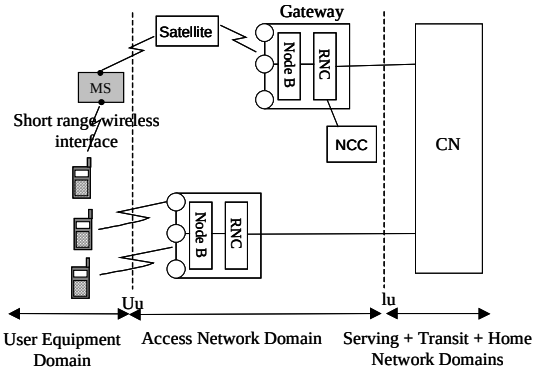

Figure 3: Individual configuration

III.I.II.I 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 intermediate module 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.

III.I.II.II 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.

III.II 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 access to the satellite or Distributed terminal configuration: an external module enables a terrestrial terminal to benefit from broadcast services offered by the S-UMTS. The inter-connection between the terminal and the external module can be realised using short-range wireless technology.

Direct access to the satellite or Integrated terminal configuration: the terrestrial terminal contains embedded functions to benefit from the broadcast services.

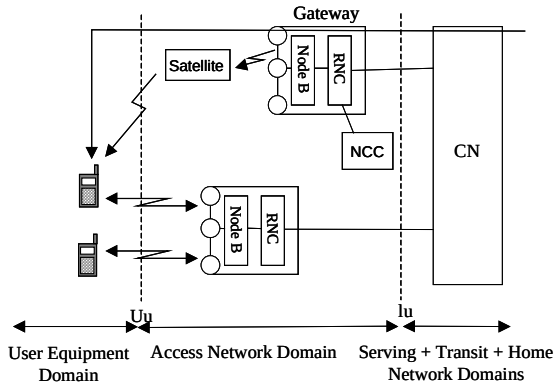

Figure 4: Direct reception from the satellite

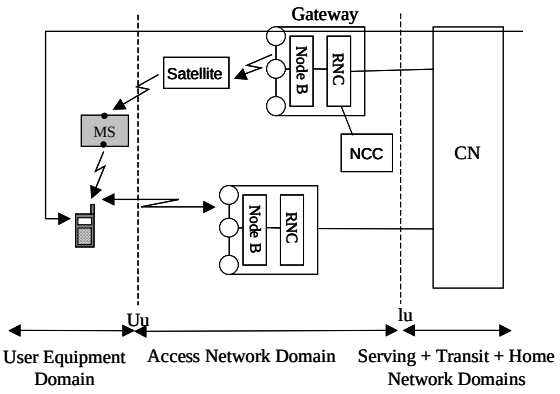

Figure 5: Indirect reception from the satellite

The two figures above show that the user benefits from broadcast/multicast services either with an integrated or a distributed terminal. Another configuration could be envisaged which would provide transport for broadcast/multicast traffic towards BSs typically the High Rate Packet Node. This would enable lower congestion within the UTRAN. The system aims at supporting all uni-directional services. Broadcast will be supported for public information and multicast for value added services. Terminals equipped with positioning devices can filter useful broadcast/multicast information according to their geographical location, their subscriber profile or other criteria.

III.II.I Gap filler concept

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 two broadcast scenarios shown in Figure 4 and Figure 5 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 gap filler is the better solution to solve the problem of urban area satellite coverage. The gap filler 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. The nature and the position of the Gap fillers will be further investigated in SATIN project.

IV. Space segment selection

The space segment is one of the basic components of any satellite system. Two choices must be made regarding the type of satellites (GEO or a non-GEO constellation) and the type of payload (transparent and regenerative).

IV.I Payload aspects

The main functional added-values that the space segment can bring, additionally to its traditional signal amplifying function, can be summarized by:

Connectivity: transparent analogue or digital processors can offer a layer 1 connectivity between spotbeam and/or frequency channels, thus allowing either regional (among a few spot-beams) or global (through the whole satellite coverage) connectivity in a single satellite hop; this is of particular interest in case of a multi-beam coverage. Regenerative payloads can further improve the granularity of the connectivity by implementing layer 2 circuit/packet switched functions, or multiplexing functions.

Link performance enhancement: on-board demodulation/re-modulation and possible decoding/re-encoding functions alleviate the constraints put on transmission performance and, as a consequence, on their cost. Low cost satellite terminals are usually characterised by low level transmitting power and poor local oscillator stability that could prevent to meet link budget through a transparent payload.

Flexible use of the satellite resource: this aspect is closely related to the level of granularity that the satellite payload possesses (i.e. on-board access to, for example, layer 2 packet), and also to resource management techniques (which allows to allocating of a given resource -channel, carrier, slot- to a specific demand more or less dynamically and care for minimising congestion occurrence). Digital regenerative on-board processor enables on-board buffering and statistical multiplexing of layer 2 resources. These two functions contribute to the improvement of the resource management.

From the above argument, a hybrid payload looks promising to handle the mixture of needs in a balanced and cost-effective manner. A space segment based on digital bent-pipe with multi-beams will surely not meet all the services requirements identified (but still meet most of them), and will probably be less effective. On the other hand it is open to waveform upgrades, less complex and based on well-tried techniques and technology.

IV.II QoS and resources management

Although the IP QoS framework does not come directly into play in the RAN procedures, ultimately these procedures have to serve the QoS requirements of IP (TCP and RTP/UDP) flows. There are a number of points that can be made regarding the issues arising here:

TCP-adaptive flows: In a satellite environment, the problems that TCP face when crossing wireless, error-prone links are aggravated mainly due to the higher propagation delay. Quite evidently the larger the propagation delay, the more adverse the effects on the TCP throughput, implying that in this context a LEO constellation is preferred over a GEO. On the other hand LEO constellation introduce variable RTTs, which impose difficulties on the TCP congestion control mechanisms (timers, ACK sequence etc). Things become worse in cases where the connection path involves more than one LEO satellites that is when a LEO regenerative payload is under consideration, since the variation of the connection's RTT increases given an increased probability of a handover within the satellite constellation.

Real-time flows: Regarding the RTP/UDP flows that will bear the real time services, the conclusions are in a sense similar; that is a GEO satellite introduces more difficulties for interactive, services such as voice (the UMTS conversational class of service) especially when the payload does not have on board switching functionality. In this case direct single-hop, mesh connectivity is not feasible and the end-to-end delay for two users of the satellite network exceeds the upper limit of 400 ms end-to-end delay. On the other hand a LEO constellation might introduce more jitter and affect jitter-sensitive services (e. g impose a larger playback buffer for streaming applications)

Call admission control: The resource management procedures and the CAC function in S-UMTS face extra challenges due to the time varying capacity available (particularly LEO/MEO) to the calls/connections served by the network. The task of preserving the required QoS/GoS while making an efficient utilization of the network resources becomes even more difficult as a direct consequence of the increased mobility of the satellites and the variability of the network (particularly if ISLs are assumed). There are ways around these difficulties [SWIK00], [MERT99] relying on the periodicity of these orbits that allows some prediction of the future capacity changes. However they demand efficiently accurate positioning methods and introduce significant complexity to the system.

IV.III Session Initiation Protocol (SIP) in S-UMTS

The S-UMTS is regarded as an access network to the all IP-based core network, and SIP functionality is mainly found in the IP multimedia (IM) subsystem in the core network. Thus S-UMTS only relays SIP messages to the respective SIP servers, i.e. Call state control functions (CSCF). Therefore SIP messages are transparent to S-UMTS. Therefore the type of constellation used for S-UMTS does not have much impact on the performance of SIP. However, the only impact (foreseeable) that satellite UMTS has will be the longer propagation delay.

Entities that are able to parse SIP messages are those that are SIP-enabled (in UMTS, they will be UEs and CSCFs). S-UMTS with bent pipe configuration will not parse SIP messages. Likewise, satellite with on-board processing will not parse SIP messages (this is because the protocol stack will go up to the IP layer at the most, but to parse SIP, it needs to go up to the application layer) either. These conclude that the capability of the satellite has no impact at all on SIP.

IV.IV Mobility in IP based S-UMTS

If the GEO constellation is used, there will not be big differences between cellular IP and IP based S-UMTS in terms of mobility management except for the long delay which will increase the handover delay. But for non-GEO cases, three types of handover are possible. The effectiveness of each handover depends on the capability of each node in the network and IP adaptation to each node.

Spotbeam handover: It can be considered as micro mobility. The rate is very high. There should be very efficient handover mechanism to guarantee required QoS with packet mode.

Satellite handover: This can lead to micro mobility or macro mobility depending on the connectivity of the satellite with the ground station.

FES handover: This comes under macro mobility.

Location management is not that crucial compared to handover. But still location management with GEO is much easier than with non-GEO. But it does not directly contribute to QoS improvement of the system except in saving signalling load.

IV.V Multicast

Multicast applications fit better in the GEO paradigm. Their wide coverage in combination with the complexity related to implementation of multicast (IP or not) within a satellite constellation [WOOD01] renders GEO more appropriate for this purpose. Particularly regenerative satellites with on-board switching capabilities can be beneficial for the system capacity budget –a packet needs only to be transmitted once at the uplink and can be copied multiple times on board.

V. Multiplexing mode (FDD/TDD) selection

There are a number of aspects to be taken into consideration, and for each aspect there are advantages and disadvantages for any technique. However, it may be appropriate to critically review some of the claims usually put forward to sustain the TDD case, with reference to the satellite application;

TDD allows significant terminal size reduction: It is obviously true that for TDD a frequency duplexer is not needed; however to limit adjacent band interference, a high quality RF filter (with its insertion loss) is still a necessity. Furthermore, for FDD duplexers of the same size as the ones used in T-UMTS terminals may be used in S-UMTS terminals provided that the satellite e.i.r.p. is sufficiently large to compensate for the low G/T figure yielded by these duplexers. For the sake of fairness, it should be added that some circuit reuse is possible for TDD and that the CPU never operates simultaneously over forward and reverse link bursts, thus saving battery power.

TDD handles efficiently asymmetric traffic: It is not possible to accommodate the asymmetric traffic requirements of every single user, but only those of the aggregate traffic, which in general is less unbalanced (in particular for multicast services). Secondly, even considering the aggregate traffic, it should be clear that in a multibeam scenario the necessary degree of intra and inter beam switching point synchronization will largely reduce the flexibility of TDD.

TDD efficiently exploits channel reciprocity: Unfortunately, at the FES and on-board the satellite, channel reciprocity is spoiled by the fact that the propagation delay is large with respect to the channel coherence time. Channel reciprocity may be exploited at the MT.

These facts certainly do not rule out the TDD option, but somewhat reduce its appeal at least for the satellite scenario. The choice of FDD option becomes a necessity when the most relevant issues in selecting the duplexing mode are the following:

- Spectrum allocation;
- Opportunity of exploiting commonalities with T-UMTS;
- Flexibility in adapting to ever-changing market and traffic scenarios.

VI. Conclusions and future work

The services and market aspect has been discussed and the potential of broadcast and multicast service in S-UMTS has been stressed. Different S-UMTS architecture scenarios have been introduced. A 'Gap filler' concept to target the mass market, has been suggested. As a first step in defining the reference architecture for S-UMTS, selection of satellite constellation and payload has been investigated considering different aspects such as QoS provision and resources, SIP, mobility management and mutlicast. GEO has been considered as the most promising candidate for the space segment. Hybrid type payload with some switching functionality would best serve the S-UMTS service requirements. Selection of multiplexing modes for S-UMTS have been discussed. The FDD was recommended as the best candidate for S-UMTS considering the terminal and payload complexity and interoperability with the T-UMTS.

Future work will focus on selecting the reference architectures for S-UMTS and defining the functional and physical entities and interfaces between entities of the selected architectures in depth. The defined architecture will be validated through simulation.

ACKNOWLEDGEMENTS

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Reference

[ETSI00] Satellite Component of UMTS-IMT 2000; General Aspects and Principles, Draft ETSI TR 000054 V0.1.0 (2000-12).

[SWIK00] Siwko J., Rubin I., 'Call Admission Control for non-geostationary orbit satellite networks and other capacity-varying networks', Int. J. Sat. Com; pp. 87-106, March-April 2000

[MERT99] Mertzanis I, 'ATM QoS Provisioning over Broadband Satellite Networks', Ph.D Thesis, Oct 1999.

[WOOD01] Wood L, et al; "IP Routing Issues on Sat. Constellations', Int. J. Sat. Com; Jan–Feb 2001.