PASSENGER MULTIMEDIA SERVICE CONCEPT VIA FUTURE SATELLITE SYSTEMS

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1 ABSTRACT

In this paper, a innovative service concept for aircraft cabins is presented. Aircraft multimedia services will be offered to passengers soon via back-seat screens and IP cable networks. In this paper also wireless access methods such as W-LAN for data connections to laptops and UMTS for personal telephony are suggested. A concept for service provisioning of dedicated aircraft services and its architecture is described. Different services are multiplexed over a satellite link and forwarded to the service provider domain. Dynamic bandwidth support for the different services is supported and handover between satellites are supported.

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1. INTRODUCTION

The demand for making air travel more pleasant, secure and productive for passengers is one of the winning factors both for airlines and the aircraft industry. Design studies for airlines and market survey of in-flight network providers show the necessity for high data rate communication services for airliners, with an obvious trend towards in-flight entertainment (IFE), Internet applications and personal communications. Today, aeroplanes seem to be the last remaining islands where mobile communications and Internet access is not available. While security and passenger safety have always been of prime concern, recent acts of international terrorism have clearly demonstrated the need for major improvements and new initiatives in these areas. Such developments can be brought about by the use of the latest in communications technologies. Moreover, people are becoming more and more used to personalised equipment, such as mobile phones, laptops or PDAs, all accommodated with their own personal environment. Thus, thinking of future mobile communication from a user acceptance point of view, there is a clear demand for a **wireless access** solution for multimedia and personal communication services through users own equipment. Besides, a wireless network might also support the airline personnel (cabin crew, maintenance crew) during their daily work (e.g. for mobile data access).

In what follows in this paper we present an service concept and architecture that enables the use of personal wireless communication devices inside an aircraft cabin.

2 AERONAUTICAL SERVICE CONCEPT

The service scenario considers travellers in aircraft on the move. Future airliners will provide a variety of entertainment and communications equipment to the passenger to make the journey more pleasant through in-flight entertainment, more productive through business communication facilities, and more secure through tele-medicine and surveillance facilities on board. A variety of services is needed, each having a different bandwidth demand and different types of communication protocols. Many of the services will be available to the passenger by means of cabin-installed equipment, such as TV screens, a rescue compartment with tele-medicine equipment, or fixed installed satellite phones. Since people are becoming more and more used to their own communications equipment, such as mobile phones and laptops with Internet connection, either through a network interface card or dial-in access through modems, business travellers will soon be demanding wireless access to communication services. So far, GSM telephony is prohibited in commercial aircraft due to the uncertain certification situation and the expected high interference levels of the TDMA technology. With the advent of spread spectrum systems such as UMTS and W-LAN, and low power pico-cell access such as Bluetooth™, this situation is likely to change, especially if new aircraft avionics technologies are considered, or if the communications technologies are inline with aircraft development as today for the new Airbus long-haul A380 aircraft. With small business jets such as Bombadier LearJets, Gulfstream etc., individual equipment certification is already established.
When wireless access technologies in aircraft cabins are envisaged for passenger service, the most important standards for future use are

considered to be: UMTS with UTRAN air interface, Bluetooth™, and W-LAN IEEE 802.11b. Of course, these access technologies will co-exist with each other, beside conventional IP fixed wired networks. The wireless access solution is compatible with other kinds of IFE, such as live TV on board or provision of Internet access with dedicated installed hardware in the cabin seats. Hence, it should not be seen as an alternative to wired architecture in an aircraft, but as a complementary service for the passengers. For instance, access to VPN or the possibility of being reachable under the user's telephone number while flying, will become real with the network architecture.

The architecture and its components are conceptually depicted in Figure 1. Such an infrastructure comprises of:

- Several wireless access segments in the aircraft cabin, namely a wireless LAN according to IEEE 802.11b standard for IP services, an UMTS pico-cell for personal and data communications, and Bluetooth™ 1.1, as well as a standard wired IP LAN.
- A satellite segment for interconnection of the cabin with the terrestrial telecom networks. The different cabin services must be integrated and interconnected using a *service integrator,* that allows the separation and transportation of the services over a single or several satellite bearers. Peculiarities, such as limited bandwidth, asymmetric data rates on satellite up- and down-link, and dynamic traffic demand between the different services and handover between satellite bearers need to be addressed. In order to minimize the cost (satellite resources) for a given QoS efficient interworking between the service integrator and the satellite segment will be required.
- An aircom service provider segment supporting the integrated cabin services. The aircom provider segment provides the interconnection to the terrestrial personal and data networks as well as the Internet backbone. For the UMTS cabin service, a subset of the UMTS core network must be available.

The provision of such a collectively mobile heterogeneous network requires the development of new protocol concepts to support

- the integrated services with dynamic bandwidth sharing among the services and asymmetrical data rate;
- IP mobility and virtual private networks (VPN) for the individual passengers in the mobile network;
- authentication, admission and accounting (AAA) in the mobile network, especially taking into account the necessity to support different pricing concepts for each

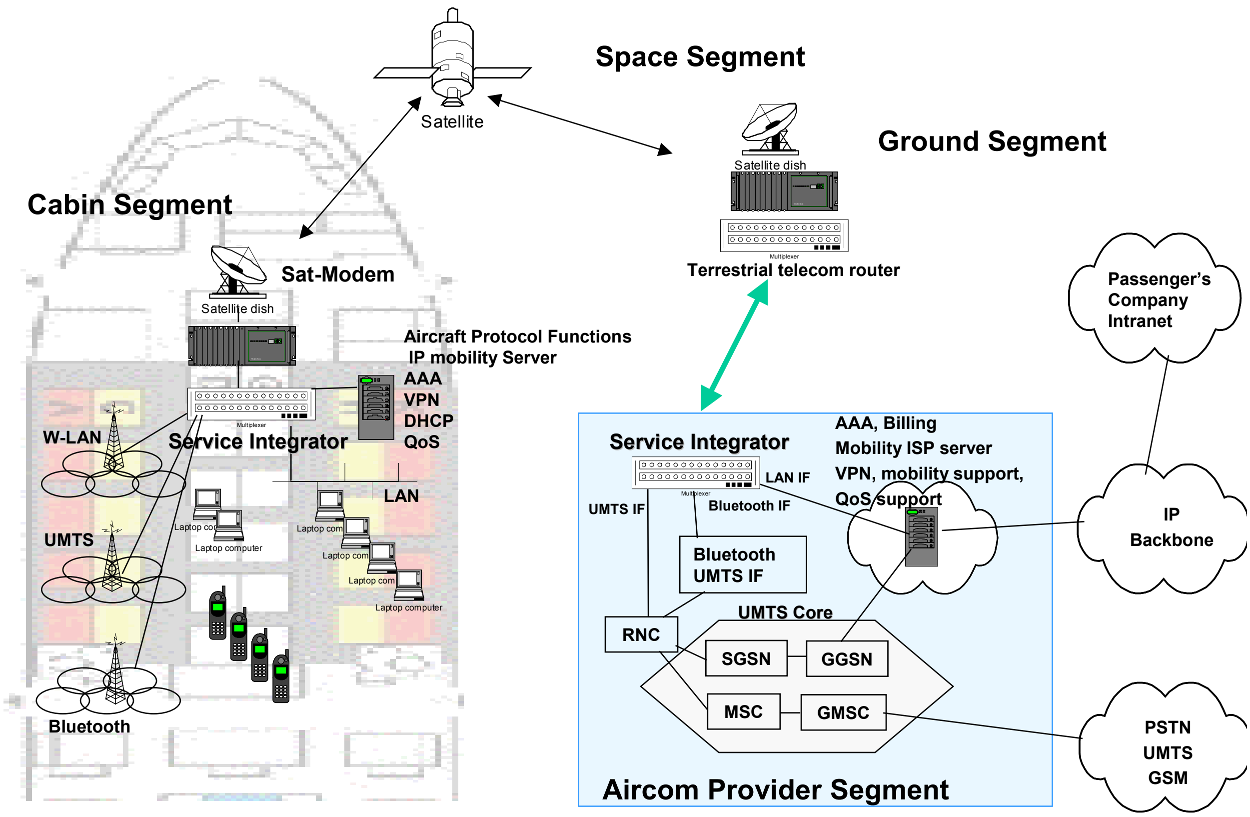


Figure 1: Network Architecture

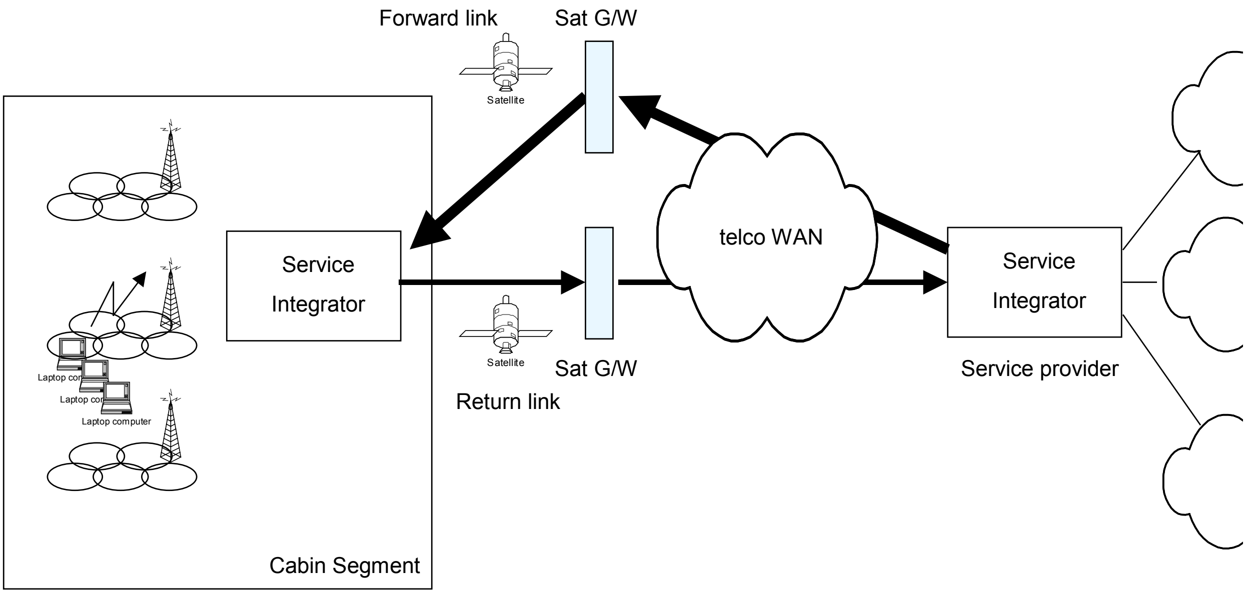


Figure 2: Satellite Connection Scenario

passenger in the mobile network and the interaction of airline, satellite provider, aircom service provider and terrestrial service providers.

Satellite Connection

Connection to telecom networks is considered to be achieved by satellites with large coverage areas [LWJ00], especially over oceanic regions during long-haul flights. The service concept needs to take into account today's peculiarities of satellite communications, thus it must cope with the available or in near future available satellite technology, and interworking must be performed at aircraft interface level with the satellite segment, cf. Fig. 2:

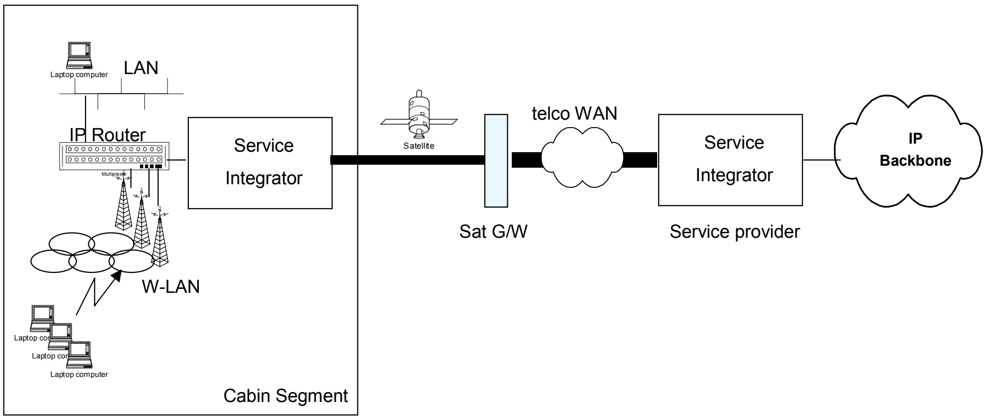
- Only restricted satellite data rates will be available in the near future; thus the bandwidth that is requested by standard interfaces of the wireless standards needs to be adapted to the available bandwidth (typically: 432 kb/s in down-link, 144 kb/s up-link (Inmarsat B-GAN™), or 5 Mb/s in down-link, 1.5 Mb/s in up-link (Connexion™ by Boeing)). Furthermore, dynamic bandwidth management is needed to allocate higher bit rates from temporarily unused services to other service.
- Currently, few geostationary satellites such as the Inmarsat fleet are available for two-way communications, that cover the land masses and the oceans. Ku-band may be used on a secondary allocation basis for aeronautical mobile satellite services (AMSS) but bandwidth is scarce and coverage is mostly provided over continents. K/Ka-band satellites will be launched in the near future, again here continental coverage is mainly intended. The scenario must thus consider
    - the use of different satellite systems, which will probably force the support of different service bearers, and
    - **handover** between satellite systems.

  It is assumed that each satellite segment is connected via terrestrial wide area networks or via the IP backbone to the aircom service provider.
- Asymmetrical data rates in satellite up- and down-links, that may also be caused to operate in conjunction with different satellites systems for up- and down-link. The service portfolio in the cabin and the service integration needs to cope with this possibility.

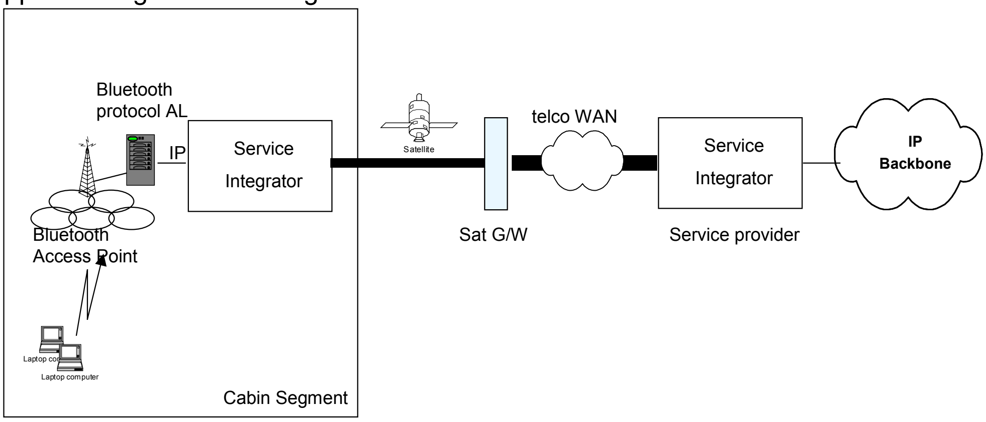
3 SERVICE ARCHITECTURE

The different wireless access services of UMTS, W-LAN and Bluetooth require different architectures from a protocol and networking point-of-view, as depicted in Figure 3. The central part of the service portfolio provisioning is the service integrator, which will be described later in detail. The service integrator will provide the interfaces for the wireless and wired service access points in the cabin, as well as the interface to the terrestrial networks at aircom provider site. All services will be bundled and transported between a pair of Service Integrators.
In the simple case of native IP, a router can connect the wired LAN segment and the wireless IEEE 802.11b access points. Furthermore, other protocol entities needed for IP services in the cabin (such as

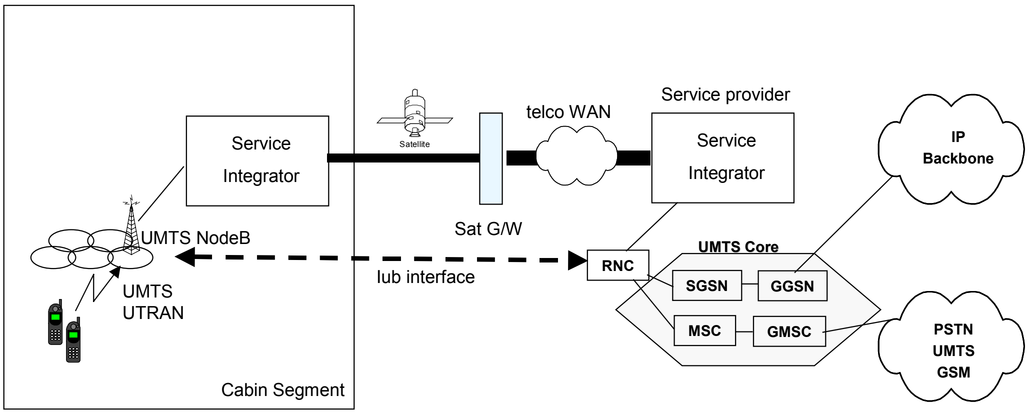
DHCP, mobility and AAA server) are linked here. The situation is similar for the case of IP over



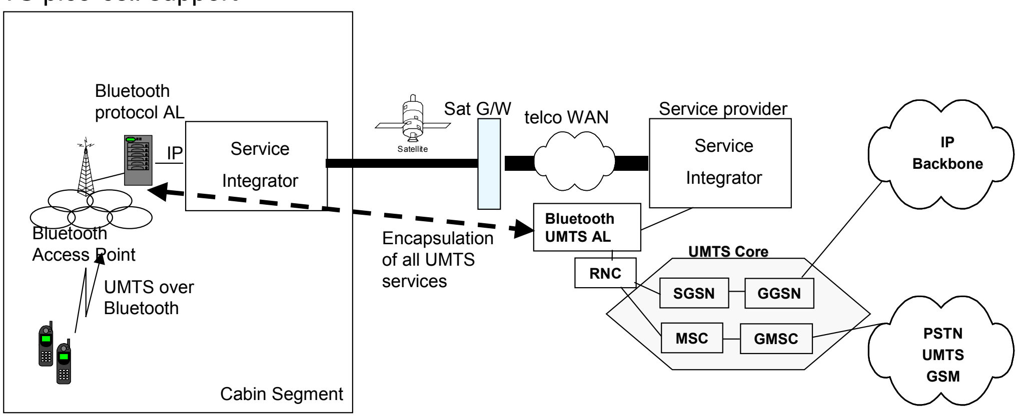
a) IP support through fixed cabling or W-LAN



b) IP support through Bluetooth™ access



c) UMTS pico-cell support



d) UMTS support through Bluetooth™ access

Figure 3: IP Service Network Architecture

Bluetooth™, except for the different air interface. In the figure, an adaptation layer (AL) is shown, which will be needed for the UMTS encapsulation (see below). From a functional point of view the AL is not necessary for native IP service, however all IP streams from Bluetooth™ must be fed through this instance.
The UMTS access in the cabin opens up many research activities. The first question aims at the type of access node in the cabin. It will be discussed whether only a Node B is required in the cabin, while the Radio Network Controller (RNC) can be located at aircom service provider premises. Here, the UMTS core network is interconnected and the passenger's data and signaling traffic are served. The protocol mapping between RNC and Node B onto the service integrator stream, the effect of the propagation delay, delay jitter, and finally the effect of the limited bandwidth and variable bandwidth assignment must be thoroughly investigated and appropriate countermeasures (if needed), for instance through adaptation layers will be designed during the project. It might however be more attractive to have a combined Node B/RNC pico-cells on the aircraft, or even combined pico-cells with Node B/RNC/SGSN, since having the I_{ub} interface over the satellite might not be desirable from a signaling overhead point of view. In addition, MAC functionality is situated in the RNC and providing efficient QoS might be difficult.
A new idea is followed in the project: to use Bluetooth™ access as radio interface for UMTS in replace of the UTRAN. The advantages of such an approach are obvious: smaller cells yield higher capacity at lower interference and better frequency reuse. New cell phones (e.g., Ericsson T39m, Nokia 6310) are already equipped with Bluetooth™ interface. The standard can be used to transmit the UMTS services to a small Bluetooth™ base station, like in a DECT system. From the Bluetooth™ access point the UMTS services (data and signaling traffic) have to be encapsulated and transmitted to the UMTS core network. The questions to be addressed are again: the type of transport protocol over the satellite, the impact of the delay, the restrictions caused by the available bit rate, and the design of the adaptation layer. In case that UMTS pico-cell is used in the cabin, the Bluetooth™ access would be directly connected to the pico-cell controller rather than using the service integrator for transportation to the ground segment.

From the previous discussion it is clear that the mixture of services and protocols to be interconnected by a satellite bearer with terrestrial ground infrastructure represents a new networking approach for a mobile network. This concept is called a *collectively mobile heterogeneous network* on the move which is described in the next section.

4 CMHN - COLLECTIVELY MOBILE HETEROGENEOUS NETWORK

The Collectively Mobile Heterogeneous Network (CMHN) (cf. Figure 1) consists of the mobile part aboard the aircraft and of the fixed service provider infrastructure on the ground. Both parts are interconnected by a bearer service between two Service Integrator (SI) nodes. Typically, one or more satellites will provide the bearer system.
This SI module will be responsible for switching data among the wireless access standards that will coexist in the aircraft (UMTS, IEEE 802.11b for W-LAN or Bluetooth™). Other functional entities for mobility support, such as accounting may be

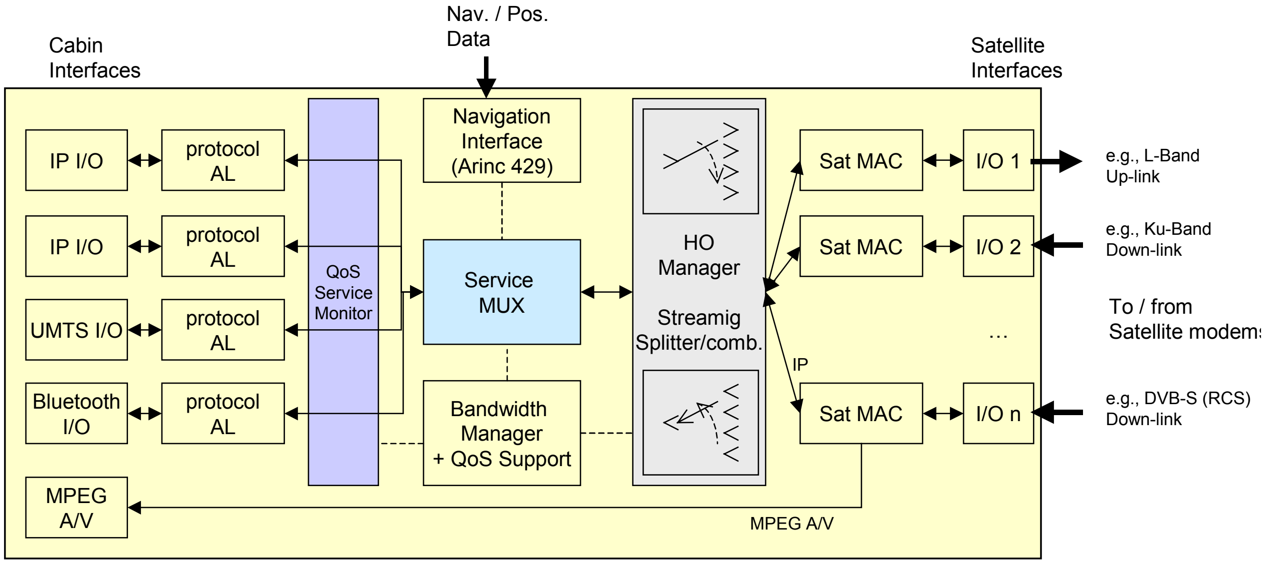


Figure 4: Service Integrator: core of the Collectively Mobile Heterogeneous Network

required and are described below.
The network concept is called *mobile* since the access network of the subscribers itself is on the move, and the topology with respect to the fixed service provider will change (coverage by different satellites, ground earth stations). The SI is in charge of handling this kind of mobility to provide a seamless transparent connection between cabin and service provider.

The concept is called *collectively mobile* since mobility is achieved for many nodes (terminals) inside the mobile network. New protocol functions are required to support the mobility for each individual node inside the network, and virtual private networks (VPNs). Also accounting is an innovative task in the CMHN since fees may vary in the different transport bearer networks, and all kind of services need to be supported (packet switched, circuit switched).

The concept is called *heterogeneous* since several access standards (UMTS, W-LAN, Bluetooth™) are supported. These standards typically use completely different protocol stacks.

The central part of the CMHN is the SI. Figure 4 shows its block diagram. A service multiplexer will allow the combination of the different transport streams of the access networks. This multiplexer is envisaged to assign variable capacities to the streams, controlled by a bandwidth manager that monitors also the QoS requirements of the different service connections. Changes in capacity assignment must be signalled to the SI at the other communication end. The heterogeneous traffic stream is then sent to streaming splitter/combiner. This unit is envisaged to support several satellite segments and to perform handover between them. Asymmetrical data rates in inbound and outbound directions can be managed here. Adaptation to the supported satellite segments are done by medium access controllers (MAC) in a modular manner. Towards the terminal side, the interfaces of the wireless access standards need to interwork with the transport streaming of the SI by specific adaptation layers (AL). These ALs have to be designed according to the analysis of the impact of delay, jitter and restricted / variable bandwidth on the protocol stack. Buffering (to compensate delay jumps at handover) and jitter compensation for real-time services (e.g., voice) must be also provided here. Above scheme was submitted for patenting in [HJ02a].

As an example, MPEG A/V streaming from digital video broadcast satellites (DVB) can be also be fed through, while IP data streams can be used for the service stream of the SI.

Note that in Figure 4 only the SI block diagram for the cabin case is shown. The terrestrial counterpart at the aircom service provider premises will have a different interface towards the satellite segment, for instance IP/ATM networking interfaces or an inverse multiplexer for dialled lines.

The concept of the CMHN requires also new approaches for authentication, admission and accounting (AAA), and for mobility and VPN support. The different providers in the network scenario must

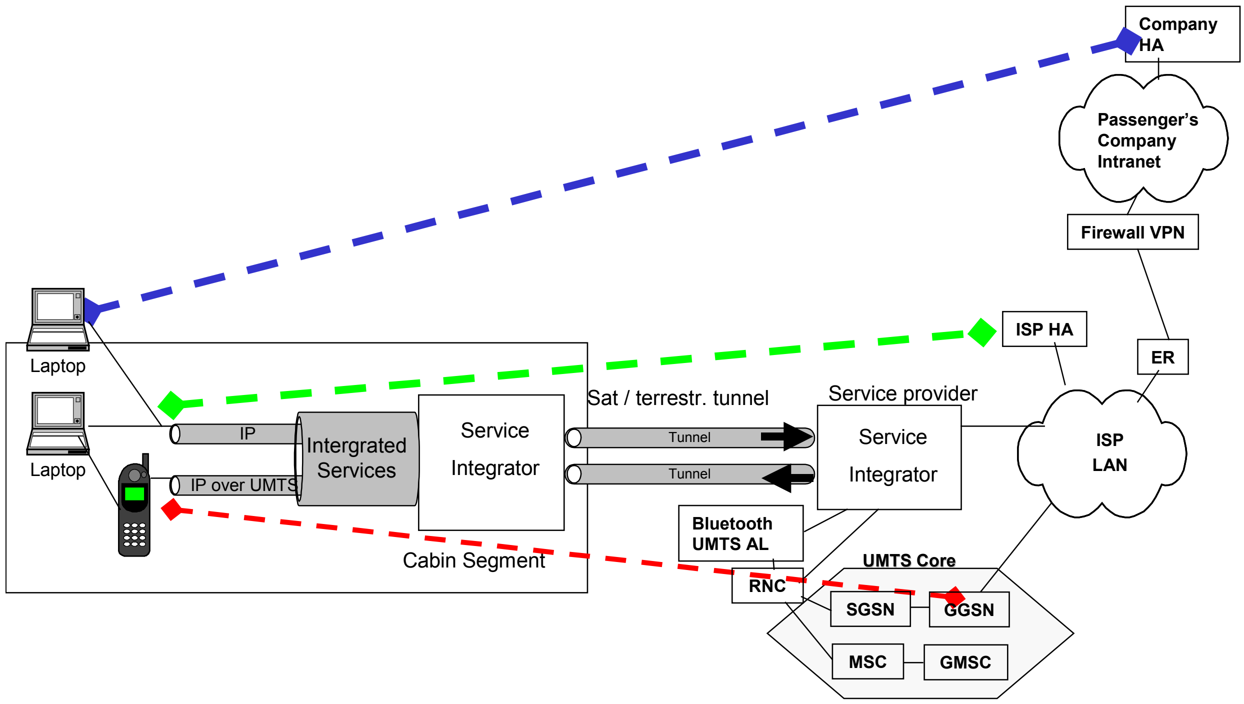


Figure 5: Mobility Concept

be considered: the satellite segment providers, the terrestrial network carriers for interconnection between aircom service provider and satellite ground earth station, the terrestrial backbone or PSTN networks, the airline as reseller, and the aircom service provider itself. The latter will act as mobile network provider for UMTS. The airlines as service reseller to the passengers may wish to have different tariffs and pricing scenarios, such as volume-based pricing, time-based pricing, flat rates for business travellers, or even service charge included in the ticket prices, or service dependent pricing (UMTS, W-LAN). Thus, a manifold of accounting methods should be supported. While UMTS offers already most accounting methods inside the UMTS core network, IP based accounting methods must be developed in this project, coping with the CMHN concept. Since IP traffic at IP connection level can be monitored only before the IS stream multiplexing, it is envisaged that AAA functions must be located in the cabin to monitor for instance, volume-based accounting. Counterparts of the AAA function must be located at the service provider site, and appropriate signaling functions between both entities must be foreseen.

The IP mobility [RFC2002, Per98, Sol98] management for the individual users and VPN support is another challenging task of this project. The difficulties are depicted in Figure 5. While IP mobility for one network on the move with several attached users has already been tackled in [HJ02], we find in the CMHN concept several networks with IP users. In the SUITED approach the IP stream was intercepted by an interworking unit that provided a seamless handover and mobility support over the access network which was not visible to the terminals. Since the IP stream in the CMHN is ending directly in the mobile handsets or the laptops, and since one goal of the project is, to provide all services at user level with **no** modifications to hardware or software in order to obtain user acceptance, such an approach is not possible. Moreover, Figure 5 shows that in the CMHN the end points of the signaling and traffic streams vary for the different services. While VPNs want to tunnel end-to-end between terminal and corporate network, the integrated service stream tunnels from IS to IS. The IP service will be directly terminated at terminal side. An extension of the tunnels until the GGSN of the UMTS network is only possible for native IP services, when the tunnel could be extended by unsolicited tunneling using a Home Agent functionality at the aircom provider site by the use of IP addresses from the aircom service provider domain. However for the UMTS service this is considered impossible for the individual connection since we must assume that the UMTS core network will provide only one IPv4 address for the whole UMTS cabin cell. Instead IP address spoofing and proxy techniques must be investigated at IS interworking level. This again will impact on the design of the adaptation layer protocols. Solutions for IPv6 seem to be less complex due to the huge address space.

5 ACKNOWLEDGEMENT

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