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Interworking Evolution of Mobile Satellite and Terrestrial Networks

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ABSTRACT

There is considerable interest among mobile satellite service providers in interworking with terrestrial networks to provide a universal global network. With such interworking, subscribers may be provided a common set of services such as those planned for the Public Switched Telephone Network (PSTN), the Integrated Services Digital Network (ISDN), and future Intelligent Networks (IN's).

This paper first reviews issues in satellite interworking. Next the status and interworking plans of terrestrial mobile communications service providers are examined with early examples of mobile satellite interworking including a discussion of the anticipated evolution towards full interworking between mobile satellite and both fixed and mobile terrestrial networks.

INTRODUCTION

Mobile Satellite Services (MSS) were first introduced in 1979 by Inmarsat and its member signatories to provide communications to ships at sea. These services have been systematically extended to include land and air applications. Service is now provided worldwide through satellites in each of four ocean regions. Australia is the first to have a domestic full service system with the launch of AUSSAT B1 in 1992. North America will be the first to have a regional telecommunications system (MSAT) with deployment scheduled for 1994 (messaging-only systems are now in operation by TMI in Canada, and AMSC and Qualcomm in the U.S.). These current generation systems are all based on the use of conventional geostationary satellites. Systems using a number of non-geostationary satellites are being proposed (Inmarsat P, Odyssey, Aries, Ellipsat, Iridium, Globalstar) that will provide communications to hand-held terminals around the turn of the century.

Fundamental to all of these systems is a desire to interwork with the existing terrestrial fixed and (in some cases) mobile networks. Interworking is the capability of separate networks to provide transparency for a common set of services and features. Of interest are those to be made available in the PSTN, the ISDN and the IN e.g. Universal Personal Telecommunications (UPT).

Furthermore, while the current focus in mobile networks is on providing terminal mobility there is an interest to eventually provide personal mobility as is being proposed for the UPT service. Terminal mobility refers to the capability of the network to keep track of and communicate with the user's terminal while that terminal is in motion. Personal mobility will remove the association of the user and a specific piece of equipment. The following discusses the evolution of the terrestrial and satellite networks to provide an overview of the trends towards global interworking. The focus in this paper is on network structure, access and management and service attributes, not on specific transmission technologies used.

ISSUES IN INTERWORKING

Interworking requires that the networks recognize, coordinate and route inter-network calls. In addition, bilateral agreements are needed between terrestrial and satellite service providers for billing and funds transfer.

A key issue in interworking a mobile satellite system with a terrestrial system is mobility management. A typical satellite system will consist of a single coverage beam, a population of mobile terminals (MT's), a Network Control Station (NCS) and a gateway (GW). The NCS is responsible for intra-satellite system control including satellite channel allocation and network management. The GW is the interface to the PSTN. The next level of system complexity is one where the satellite has several spot beams. Here the PSTN interface can be (1) one GW that can communicate with the MT's in all the beams or (2) a network of GW's distributed among the spot beams.

The latter case serves to reduce the terrestrial backhaul component of the overall connection when the GW selected is the one closest to the PSTN subscriber. The next level of complexity is a system that uses several spot beam satellites to provide, at its fullest capability, worldwide continuous coverage. Here, in each satellite's coverage area GW's located in several countries will provide access to the PSTN via international trunks.

The two inter-network call types, MT-originated (MTO) and PSTN-originated (PSTN-O), differ in their interworking requirements. For a MT-O call, the MT will signal the NCS (or a desired GW if the NCS function is devolved to GW's) to establish a call. While the NCS performs mobility management within its network, in this case there is no need for mobility management between the satellite and terrestrial systems. The GW will in turn coordinate call set-up with the PSTN based on the destination subscriber's phone number. For a PSTN-O call, it is necessary to (1) indicate to the PSTN that the call is being made to the satellite network and (2) to establish the location of the MT in order to establish the appropriate GW access and routing between the PSTN and that GW.

Subscriber mobility management between the networks is facilitated by (1) a unique code that identifies a database containing the mobile's location, (2) inter-network signalling, and (3) subscriber databases. In a mobile environment these databases will include the subscriber's service profiles as well as location registers. With a satellite network unique access arrangement, the calling party need not know himself the location of the mobile destination; the networks will know that the call is to the satellite system and will coordinate the appropriate routing.

While cellular and satellite mobile systems can operate autonomously, there is considerable interest in providing an inter-network roaming capability between such networks. Mobile roaming permits a subscriber to be serviced by one or more network providers. The mobile network in which a subscriber is normally registered is known as the "home" system whereas other networks are the "visited" systems. Subscriber roaming requires that a mobile network (1) detect the presence and determine the current location in the network of a roaming subscriber, (2) authenticate his identity, and (3) obtain his home service feature set. These functions require the deployment of location registers (databases) and the use of inter-network common channel signalling.

Efforts are being directed towards providing inter-cellular/MSS roaming by providing the subscriber with a dual mode terminal. The normal mode of operation is through the cellular system with access to the satellite system when the subscriber is beyond cellular coverage. Ultimately one terminal could provide universal ubiquitous access to the networks as described below.

TERRESTRIAL NETWORK EVOLUTION

The evolution of the fixed public, mobile terrestrial and mobile satellite networks is described in terms of network architecture, services and access. Figure 1 depicts an overview of their evolution. Coarse time frames are provided.

Fixed Network Evolution

The fixed public network has evolved from one providing Plain Old Telephone Service (POTS) to one of sophisticated features, flexibility and bandwidth. The ISDN is being implemented in many countries as an architecture which will support integrated voice, data and image services through standard interfaces over twisted-pair telephone wire to a subscriber's wall jack. Telephony enhancements include features such as call forwarding, calling line identification, among others. Two levels of service are planned: a Basic Rate (BRI) Service will provide two 64 kbps and one 16 kbps channels while Primary Rate (PRI) Service will provide 23 and 30 channels depending on the country. ISDN planners are now developing broadband networks with subscriber interfaces ranging from 32-138 Mbps.

The IN is an infrastructure that allows enhanced services (e.g. 800, automatic calling card, and Private Virtual Network services) to be deployed quickly and widely without requiring modifications to be made to every switch in the network. A typical IN structure is shown in Figure 2. A subscriber's special call request is intercepted by the IN switch which sends a query to the database for the information needed by the switch to complete the call. The operating support system administers network and customer information residing in the database. The Advanced IN (AIN) will allow rapid and customized development of new sophisticated services.

The UPT service will provide ubiquitous personal mobility within and across multiple types of networks. This is accomplished through the use of a unique personal telecommunications (PT) number that identifies a user rather than a piece of equipment. Prior coordination is required between visited and home service providers to extend UPT to roaming subscribers.

Terrestrial Mobile Evolution

First Generation Systems

First generation cellular radio systems are based on analog radio transmission technology. As shown in Figure 3 a typical analog system consists of four elements : (1) the Mobile (or portable) Terminal (MT), (2) the Base Station (BS), (3) Mobile Switching Centre

(MSC) and (4) element connectivity. The MT provides access to the BS via the radio interface. The BS under MSC control manages all MT activity within its assigned cell area. The BS allocates radio channels, performs signalling and performs BS maintenance functions.The MSC is the central switching and control element for all calls between the PSTN and the BS's, as well as for MT to MT calls. The MSC monitors MT status as relayed by the BS's (e.g. on/off hook), controls MT handoff between adjacent cells in conjunction with BS's, reacts to network maintenance indications and collects customer billing data.

Unlike the European analog systems which employed differing standards, the Advanced Mobile Phone Service (AMPS) was adopted as a single analog standard in North America. A high market penetration was achieved in North America to the point where systems are now capacity-limited.

Second Generation Systems

The second generation cellular systems currently being deployed employ digital technologies in the core and radio access portions of the network (see Figure 3). In addition to more efficient use of the spectrum based on the use of digital voice compression, these new systems are characterized by distributed network intelligence, the implementation of databases, and the standardisation of network interfaces. The strategic location of intelligence (e.g. databases) allows for the centralization of relevant subscriber information for intra- and inter-network access supporting for example national/international roaming. The deployment of digital capabilities in the cellular core network together with common channel signalling between MSC's in different networks allows for the real time exchange of routing information pertaining to the location of visiting subscribers thereby providing an automatic roaming feature based on the use of one directory number (DN) without the need for a separate roamer number. An MT is assigned a DN by a cellular service provider. Blocks of DN's are allocated to an MSC and because the MSC is associated with the PSTN exchange with which it interfaces, the DN's are used by the PSTN for cellular call routing. The digital MSC can also provide PSTN services such as Call Waiting, Call Forwarding, and Voice Messaging.

Second generation systems include location register functions which provide (1) stable information on subscribers normally registered in an area, (2) dynamic information on subscribers visiting an area, and (3) data for MT/subscriber authentication when service is requested in an area. The MSC has access to the location registers for information on the current location of its own and visiting subscribers. Common channel signalling techniques support call control and associated service features.

Second generation systems will support both telephony and data services. Out-of-band MT signalling will facilitate (1) cell-to-cell handoff which assures non-disruptive data service, and (2) ISDN-type features such as Calling Line Identification, and Completion of Calls to Busy Subscribers.

The evolution to digital is expected to be slow in North America into the mid 90's as many analog terminals are already in service. This will result in a dual analog/digital mode service as a transition strategy (per TIA specification IS.54).

In Europe and in some parts of Asia the diversity of first generation standards is to be replaced by the second generation Global System for Mobile (GSM) telecommunications TDMA standard. In North America similar systems are being implemented using the TIA IS.41 series of specifications. A major area of contention for digital cellular has been the method of air access with TDMA endorsed and being tested by some carriers and CDMA by others.

Third Generation Systems

Research activities are underway to merge cellular, cordless and paging technologies in a third generation system which will be available about the year 2000 when second generation systems are expected to reach full capacity. The intent will be to provide subscribers with universal wireless access from most locations to all current and advanced service features including POTS, personal mobility, and in microcellular coverage areas, data services up to PRI-ISDN.

Third generation systems are in the relatively early stages of definition. Important areas to be addressed include a network architecture with standard physical and protocol interfaces, equipment specifications which ensure interworking compatibility with different service providers, a common spectrally efficient air interface to support all types of wireless terminals and sophisticated techniques for subscriber mobility management in pico, micro and macro cell environments. The expected substantial signalling and control traffic may necessitate the development of higher capacity and faster packet protocols and associated networks.

Personal Communications Services (PCS) encompass wireless services including second generation cordless telephone in personal communications networks (PCN). The first generation cordless services were restricted to telepoint public environment systems and in the home. PCN's are systems based on the IN architecture and permit two-way calling, handoff between cells , and support of ubiquitous coverage. PCN technology is broadly similar to that in cellular networks. However, the cells will operate in higher RF bands and be smaller. This will improve communications quality and increase network capacity. Also, the handsets are expected to be smaller and less expensive. PCS embodies the concept of a portable telephone and a unique telephone number. On the road the portable unit would operate like a cellular phone. At home or at the office the unit would be a cordless handset operating with the office PBX or the home telephone connection.

The ITU-defined future public land mobile telecommunications systems (FPLMTS) is a concept incorporating terrestrial- and satellite-delivered PCS services (see Figure 4). This will provide voice and non-voice services including personal communications with regional and international roaming. The World Administrative Radio Conference (WARC92) identified the spectral bands of 1885-2025 and 2110-2200 MHz for worldwide implementation of FPLMTS. A co-primary allocation of the bands 1980-2010 and 2170-2200 MHz was made to MSS allowing for a possible satellite component of FPLMTS. The latter provides a unique opportunity for a common satellite/ terrestrial mobile radio.

In 1988 the Commission of the European Communities launched its Research on Advanced Communications for Europe (RACE) program focused on creating the third generation Universal Mobile Telecommunications System (UMTS) by the turn of the century. UMTS will provide the functionality of cellular, cordless and paging services ubiquitously with a smart card ability which can be used to direct calls to a message system, screen calls, or answer more than one line. The UMTS recognizes the need for a unified standard at least in Europe. This is a parallel activity to that of the CCIR for FPLMTS. UMTS would include voice, video, data services and support BRI-ISDN and possibly higher rates in special environments. UMTS would use IN concepts. System functions such as location registration and handover could be handled by service control functions which offer the flexibility of service provisioning and tailoring. Elsewhere, the Wireless Information Network Laboratory (WINLAB) at Rutgers University is presently performing research into switching architectures and transmission techniques for third generation wireless networking. In Japan, NTT is performing research into an infrastructure which will support mobile-ISDN, IN and UPT services. This network is called the Intelligent Digital Mobile Communications Network (IDMN).

MOBILE SATELLITE NETWORKS

The current generation of mobile satellite systems include those presently in operation worldwide by Inmarsat and domestically in Australia as well as the regional MSAT to be launched in 1994 North America. Inmarsat operates a number of systems including Inmarsat A for high quality voice and data, Inmarsat C for store and forward data and Aeronautical for aeronautical voice and data. Inmarsat B is being phased in as a digital replacement for the original A system. Inmarsat M which will share a common access control and signalling system with B but will provide a lower cost alternative by using lower speed voice compression and lower rate data (facsimile optional) to smaller mobile and transportable earth stations. These systems all interface to the public networks through GW's called Land Earth Stations or Coast Earth Stations. The Inmarsat 1 and (the more powerful) 2 satellites use global beams whereas the Inmarsat 3 satellites (circa 1995) will operate through spot beams.

In Inmarsat M the MT may establish service by requesting a channel from an LES in its current ocean region. The selection of the LES and the implicit PSTN connection are made by the MT operator. A call from the fixed network is automatically routed to the international gateway in the originating country, and then routed to the LES supporting the dialled country code. Mobility is provided within whole continental regions, and global mobility is being studied. Inmarsat is investigating the possible use of a single network access code which would allow access from the public network without prior knowledge of the MT's location. This could require the establishment of location registers and call routing procedures for the desired MT. Interworking of M with cellular systems is being studied.

The Australian system which is called **mobilsat** is the first domestic system to provide voice/fax/data and packet switched messaging services. The AUSSAT B1 satellite provides a single national beam. A full duplex public telephony service provides connections to the PSTN and the ISDN via a gateway. Private network telephony, data and special services (e.g. emergency, position reporting) will be offered through shared or private base stations. A **mobilsat** Special Network will also be able to be interconnected to other mobile radio networks. This will be made using the customer's PABX as a common connection between the networks. An adaptor unit will be needed between the radio network and the PABX.

A form of interworking will be implemented in the MSAT system (US portion) where MT's will be required to operate in a dual cellular/satellite mode (referred to as Mobile Telephone Cellular Roaming Service). A subscriber's MT will give first preference to operation as a cellular radio, opting for operation within the MSAT system only when out of cellular coverage. Calls can originate either from the PSTN or the MT;

MT to MT calls are also allowed.

Inmarsat is in the process of defining its Inmarsat P system for hand-held terminals. P represents a natural evolution from the M, C and satellite paging systems being implemented worldwide.

With the capability of MSS systems to be deployed more rapidly at the global level than terrestrial systems, Inmarsat has adopted an interworking philosophy that is independent of the specific satellite network technology used. The intent is to have Inmarsat P as compliant as possible with the applicable CCIR FPLMTS interworking recommendations in the timescale for introduction. Should these recommendations accommodate from the outset the different technologies and parameter ranges, e.g. transmission delay, satellites with/without (i) on-board processing, (ii) inter-satellite links, (iii) in-call satellite-to-satellite hand-off, then the likelihood of a mutually beneficial evolution of terrestrial and satellite networks will be greatly enhanced.

SUMMARY

This paper has summarized the evolution of the terrestrial fixed/mobile and satellite mobile networks. Most significant is the trend towards a service convergence whereby the subscriber will, through a compact handset, be provided ubiquitous and universal access to the fixed and mobile networks.

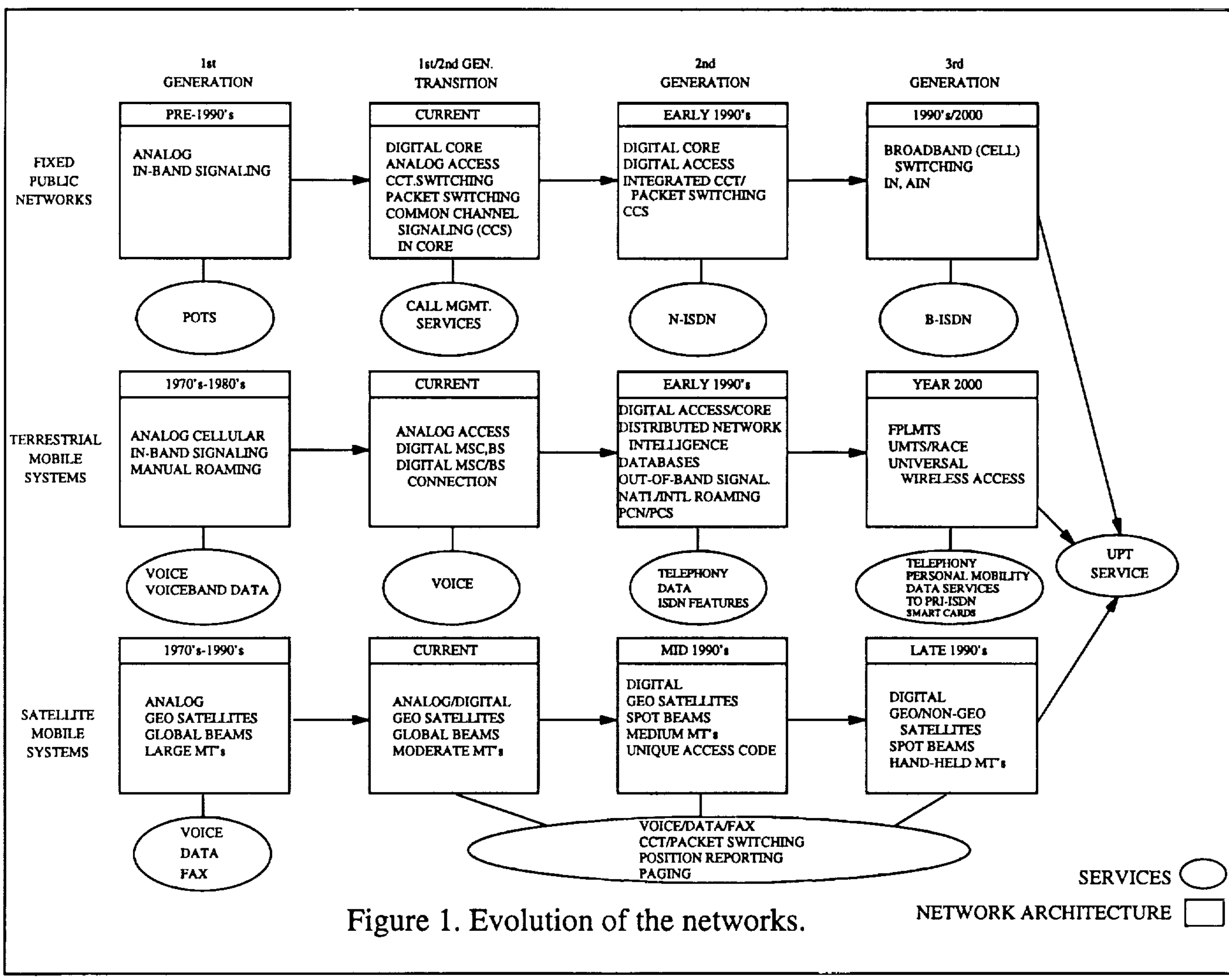

Figure 1. Evolution of the networks.

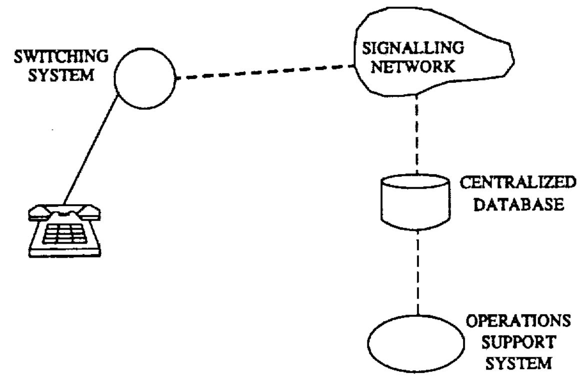

Figure 2. Intelligent network (IN) architecture.

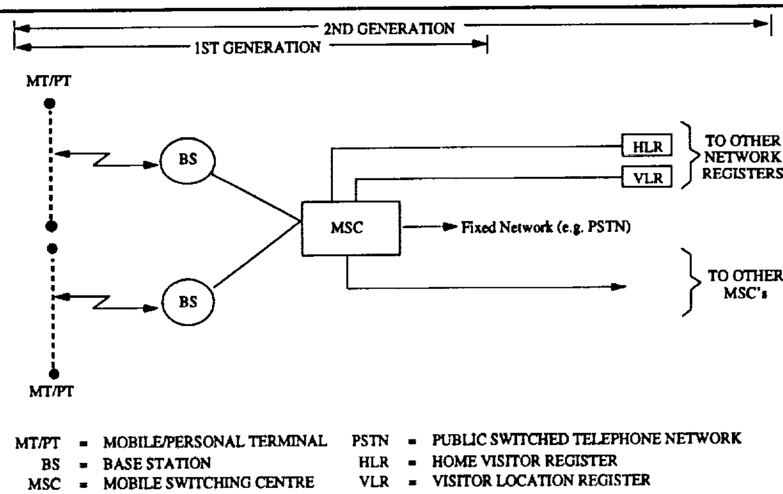

Figure 3. Typical first and second generation cellular systems.

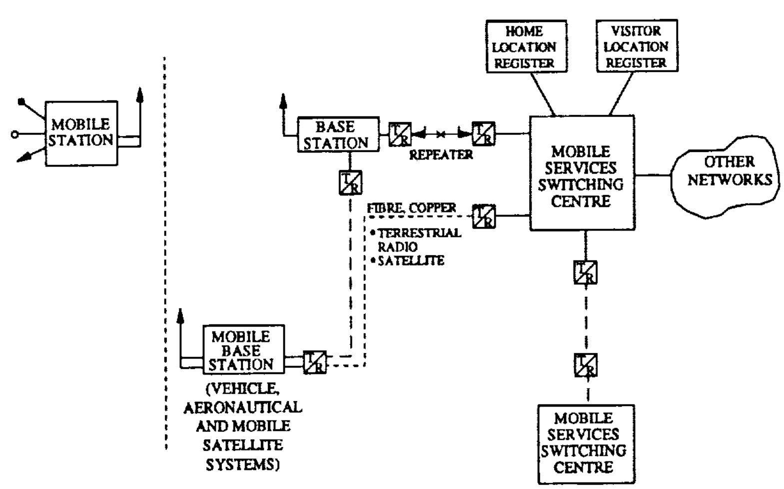

Figure 4. An example of a FPLMTS network.