

Optimisation of Mobility Management for Mobile Satellite Systems Resources

by

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The logo for the University of Surrey, featuring the word "Uni" in a black sans-serif font and a large, bold, maroon "S" to its right.

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Summary

The need to cope with the mobility of users is very different between mobile and fixed communication systems. Mobility management is thus a key feature in the design of mobile systems. Techniques derived for terrestrial mobile systems cannot be used for mobile satellite systems that use constellations of satellites. A major theme of this thesis is the proposal and verification of such mobility management schemes for mobile satellite systems.

Mobility management consists of location tracking, location area planning, positioning, location update method, paging method, signalling over air-interface and call set-up delay. New proposals are made for location updating, paging, positioning and database architectures for mobile satellite systems in this thesis.

A method of implementing intelligent paging in mobile satellite systems is outlined and a method of finding optimal location area considering both air-interface and fixed network resources is explained. It is also demonstrated how the new schemes save on signalling load in the air-interface and fixed network, satellite power, terminal power, and reduce the size of the terminal and call set-up delay.

As a basis for the above research work, features of different satellite constellations are explained with their ground tracking pattern and orbit type. The requirements of the constellation for communication purposes and the restrictions involved in achieving them are outlined. Comparison of different satellite constellation is also made. As the networking architecture and signalling of mobile satellite systems are based on the *GSM* terrestrial network, a background explanation is presented for completeness.

Key words: Mobile Satellite Communications, Constellation, Mobility Management, Location tracking, Paging, Location area, Spotbeam, Footprint.

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Glossary of Terms

<i>1G</i>	- First generation mobile systems	Research at UniS
<i>2G</i>	- Second generation mobile systems	<i>CDMA</i> - Code division multiple access
<i>3G</i>	- Third generation mobile systems	<i>CM</i> - Communication management
<i>3GPP</i>	- 3 rd Generation Partnership Project	<i>CN</i> - Core network
<i>ACM</i>	- Address complete message (ISDN message)	<i>DCCH</i> - Dedicated control channel
<i>AGCH</i>	- Access Grant Channel	<i>DLA</i> - Dynamic location area
<i>AMPS</i>	- Advanced mobile phone system	<i>DLL</i> - Data link layer/Dynamic link- library
<i>AM</i>	- Amplitude modulation	<i>DLR</i> - German Aerospace Centre
<i>AN</i>	- Access network	<i>DSSI</i> - Digital subscriber signalling- system No.1
<i>ANS</i>	- Answer message (ISDN message)	<i>DTAP</i> - Direct transfer application part
<i>ATM</i>	- Asynchronous transfer mode	<i>EC</i> - Echo Canceller
<i>AuC</i>	- Authentication Centre	<i>EIR</i> - Equipment Identity Register
<i>BCCH</i>	- Broadcast Control Channel	<i>EIRP</i> - Equivalent isotropic radiated- power
<i>FCCH</i>	- Frequency Correction Channel	<i>ESA</i> - European space agency
<i>BCH</i>	- Broadcast Channels	<i>FACCH</i> - Fast associated control channel
<i>BER</i>	- Bit error rate	<i>FBP</i> - Footprint based paging
<i>BS</i>	- Base stations	<i>FDMA</i> - Frequency division multiple access
<i>BSC</i>	- Base station controller	<i>FES</i> - Fixed earth station
<i>BSIC</i>	- Base station identity code	<i>FLA</i> - Fixed location area
<i>BSS</i>	- Base station subsystems	<i>FM</i> - Frequency modulation
<i>BSSAP</i>	- <i>BS</i> subsystem application part	<i>FN</i> - Frame number
<i>BSSMAP</i>	- <i>BSS</i> management application- process	<i>GCA</i> - Guaranteed coverage area
<i>BTS</i>	- Base station transceiver station	<i>GEO</i> - Geostationary orbit
<i>C/N</i>	- Carrier to noise ratio	<i>GMSC</i> - Gateway mobile switching centre
<i>CAR</i>	- Call arrival rate	<i>GPS</i> - Global positioning system
<i>CC</i>	- Call control	<i>GSM</i> - Global system for mobile
<i>CCCH</i>	- Common control channel	<i>GUI</i> - Graphic user interface
<i>CCH</i>	- Control channel	<i>HAPS</i> - High altitude platform
<i>CCITT</i>	- International Telegraph and- Telephone Consultative Committee	<i>HCF</i> - Highest common factor
<i>CCSR</i>	- Centre for Communication System	<i>HDLC</i> - High-level data link control.
		<i>HEO</i> - Highly elliptical orbit

<i>HLR</i>	- Home Location Register	<i>MSC</i>	- Mobile switching centre
<i>HPA</i>	- High power amplifier	<i>MSISDN</i>	- Mobile station <i>ISDN</i> number
<i>IAM</i>	- Initial address message (<i>ISDN</i> message)	<i>MSRN</i>	- Mobile Station Roaming Number
<i>IBO</i>	- Input backoff	<i>MSS</i>	- Mobile satellite system
<i>ICO</i>	- Intermediate circular orbit	<i>MSSC</i>	- Mobile satellite switching centre
<i>ID</i>	- Identity	<i>MT</i>	- Mobile terminal
<i>IMSI</i>	- International Mobile Station- Identity	<i>MTP2</i>	- Message transfer part level 2
<i>IMT200</i>	- International mobile- telecommunication 2000	<i>NASA</i>	- National Aeronautics and Space - Administration
<i>IN</i>	- Intelligent network	<i>NCC</i>	- Network control centre
<i>IP</i>	- Internet protocol	<i>N-CDMA</i>	- Narrowband <i>CDMA</i>
<i>IS-95</i>	- Interim standard-95	<i>NLOS</i>	- Non line of sight
<i>ISC</i>	- International switching centre	<i>NMS</i>	- Network management subsystem
<i>ISDN</i>	- Integrated services digital network	<i>NMT</i>	- Nordic mobile telephone
<i>ITU-T</i>	- International Telecommunication- Union-Telecommunication- Standardization Bureau-	<i>NSS</i>	- Network subsystem
<i>IWF</i>	- Interworking function	<i>OAM</i>	- Operation, Administration and - Maintenance
<i>IWTF</i>	- Internet wireless task force	<i>OMC</i>	- Operation and maintenance centre
<i>LA</i>	- Location area	<i>OSI</i>	- Open Systems Interconnection
<i>LAC</i>	- Location area code	<i>PA</i>	- Paging area
<i>LAI</i>	- Location area identity	<i>PAGCH</i>	- Paging and Access Grant Channel
<i>LAPD</i>	- Link access protocol for D-channel of <i>DSSS</i>	<i>PCH</i>	- Paging Channel
<i>LAPDm</i>	- Modified version of the <i>LAPD</i>	<i>PCN</i>	- Personal communication network
<i>LAR</i>	- Location area radius	<i>PDC</i>	- Personal digital cellular
<i>LEO</i>	- Low earth orbit	<i>PDF</i>	- Probability density function
<i>LOS</i>	- Line of sight	<i>PES</i>	- Primary Earth Stations
<i>LSTP</i>	- Local signalling transfer point	<i>PLMN</i>	- Public land mobile network
<i>LUR</i>	- Location update rate	<i>PM</i>	- Phase modulation
<i>MCC</i>	- Mobile country code	<i>PRI</i>	- Pattern repetitive interval
<i>MEO</i>	- Medium earth orbit	<i>PRM</i>	- Protocol reference model
<i>MM</i>	- Mobility management	<i>PSTN</i>	- Public switched telephone network
<i>MNC</i>	- Mobile network code	<i>PU</i>	- Pattern unit
<i>MS</i>	- Mobile station	<i>QoS</i>	- Quality of service
		<i>QPSK</i>	- Quadrature phase shift key
		<i>RAAN</i>	- Right Angle of Ascending Node
		<i>RACH</i>	- Random access channel
		<i>RMSC</i>	- Remote mobile switching centre

<i>RF</i>	- Radio frequency	<i>TES</i>	- Traffic Earth Stations
<i>RMS</i>	- Root Mean Square	<i>TLDN</i>	- Temporary local directory numbers
<i>RR</i>	- Radio resource management	<i>TMSI</i>	- Temporary mobile station identity
<i>RSTP</i>	- Regional signalling transfer point	<i>T-PCN</i>	- Terrestrial personal - communication network
<i>RVC</i>	- Reverse virtual call	<i>TRAU</i>	- Transcoder/rate adaptor unit
<i>S/N</i>	- Signal to noise ration	<i>TS</i>	- Terrestrial system
<i>SACCH</i>	- Slow associated control channel	<i>TT&C</i>	- Telecontrol, tracking and - command
<i>SAR</i>	- Specific absorption rate	<i>T-UMTS</i>	- Terrestrial universal mobile - telecommunication system
<i>SBP</i>	- Spotbeam based paging	<i>UMTS</i>	- Universal mobile - telecommunication system
<i>SCC</i>	- Satellite control centre	<i>UniS</i>	- University of Surrey (UK)
<i>SCCP</i>	- Signalling connection control part	<i>VLR</i>	- Visitor Location Register
<i>SCH</i>	- Synchronisation Channel	<i>VPC</i>	- Virtual paging cell
<i>SCP</i>	- Service control points		
<i>SDCCH</i>	- Stand alone dedicated channel		
<i>SIM</i>	- Subscriber identity module		
<i>SINUS</i>	- <u>S</u> atellite <u>I</u> ntegration into <u>N</u> etworks- for <u>U</u> MTS <u>S</u> ervices		
<i>SLE</i>	- Satellite link emulator		
<i>SMS</i>	- Short message services		
<i>SMSC</i>	- Short message service centre		
<i>S-PCN</i>	- Satellite personal communication - network		
<i>SPOC</i>	- Simulation package of orbit - constellation		
<i>SS</i>	- Supplemental services		
<i>SS7</i>	- Signalling system No.7		
<i>SUMO</i>	- <u>S</u> atellite- <u>U</u> MTS <u>M</u> ultimedia - Service Trials <u>O</u> ver Integrated- Testbeds		
<i>S-UMTS</i>	- Satellite universal mobile - telecommunication system		
<i>TACS</i>	- Total access communication - system		
<i>TC</i>	- Transcoder		
<i>TCH</i>	- Traffic channel		
<i>TDM</i>	- Time division multiplexing		
<i>TDMA</i>	- Time division multiple access		

Chapter 1

1 Introduction

1.1 Overview of the mobile satellite systems

The growth of telecommunications in the last decade has been explosive and is expected to take on a new dimension in the beginning of 21st century as complete global communication with the integration of satellite, high-altitude platforms (*HAPS*), optical fibres and terrestrial wireless technologies [1]. Such a global system will provide access to a wide variety of services from high quality voice to high definition videos anywhere anytime in the world [2]. Therefore satellite communication continues to play its role in personal communications with major advantages for wider area coverage [3]. Satellites were used in the past for fixed communication and then extended to mobile communications by ships, aircraft and land vehicles. Now in the age of personal communications, satellites are present via Iridium and Globalstar. Iridium is an extraordinary achievement from a technology standpoint, even though it was unable to grab the consumer market and failed due to the poor market prediction and the use of complex and expensive technology without flexibility. The experience of Iridium indicates that cheap and flexible mobile satellite technology is needed to fit with the rest of the telecommunication industry. Mobile satellite systems (*MSS*) [4][5] are nowadays considered to be complementary to terrestrial systems (*TS or T-UMTS*). The satellite component of the universal mobile telecommunication system (*S-UMTS*) [6][7] rather than being considered as a stand alone global communication system is considered as a complementary part of an integrated system due to the resources effectiveness and market prospective [7].

In this conjecture, it is better to figure out the similarities and dissimilarities among fixed telecommunication systems, terrestrial mobile communication systems, high altitude platform systems [8] and mobile satellite communication systems. The major difference between fixed telecommunication systems and mobile communication systems is the user movement from place to place and hence the dynamically changing wireless link between the network and the end user. These factors are similar to those with the high altitude platforms, but they can be more significant in mobile satellite systems due to the movement of the satellites (*LEO/MEO*) [9] as well as the terminal movement. Satellite systems can be both power and bandwidth limited. The power limitation comes from heat dissipation constraints on the spacecraft, solar panel power generation constraints especially at the end of satellite life time, antenna size hence gain and thus

EIRP. The bandwidth limitation comes from restricted allocation on the mobile and feeder links. Satellite systems can provide very wide area coverage, but with low capacity per unit area. On the other hand, terrestrial cellular stations provide high capacity per unit area, but each station has limited area coverage. Consequently, providing wide area coverage with terrestrial systems requires many stations with attendant real estate and landline costs. The ability of satellites to provide small cells of higher traffic density is fundamentally limited by the antenna aperture. So the advantage of each of the different systems can be exploited to realise an integrated effective and efficient global communication. The comparison between different systems is shown in Figure 1-1.

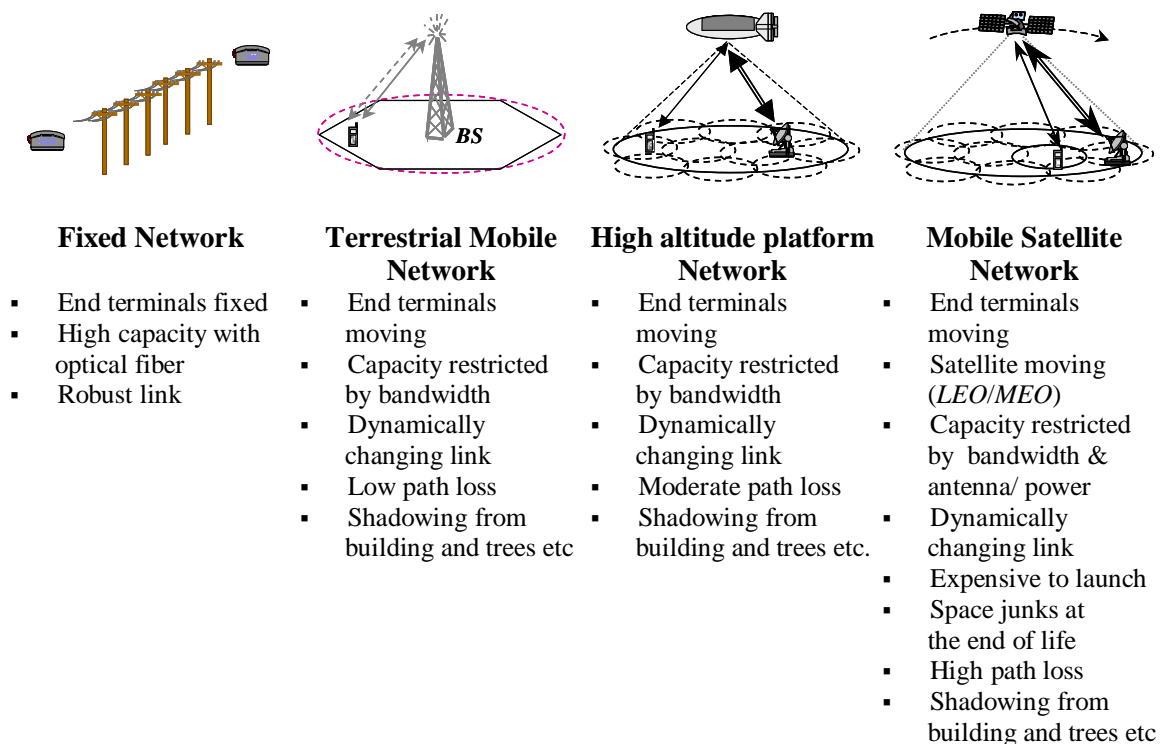


Figure 1-1: Comparison of different communication systems

As shown in Figure 1-1, the prominent feature of the *MSS* is the movement of the satellites (*LEO/MEO*). This feature creates the dynamic network topology, which eventually leads to more complicated mobility management functionalities and the vulnerable nature of the radio link through satellite between mobile station (*MS*) and fixed earth station (*FES*).

Mobility management (*MM*) functionality in mobile network takes care of the location of the *MS* when it communicates with other *MS* or a fixed terminal in the *PSTN* or *ISDN* network (*active mode*) or in silent mode (*idle mode*) for maintaining the continuity of the call and routing the call effectively when the *MS* receives a call. The *MM* process in active mode and idle mode are called *handover* and *location tracking* respectively. In mobile satellite systems *MM* should also take care of the movement of the satellite and therefore it is different from *MM* in terrestrial mobile

systems. Hence there is a need for a new or modified *MM* protocol for *MSS*. Only location tracking aspects are investigated in this thesis.

1.2 Structure of thesis

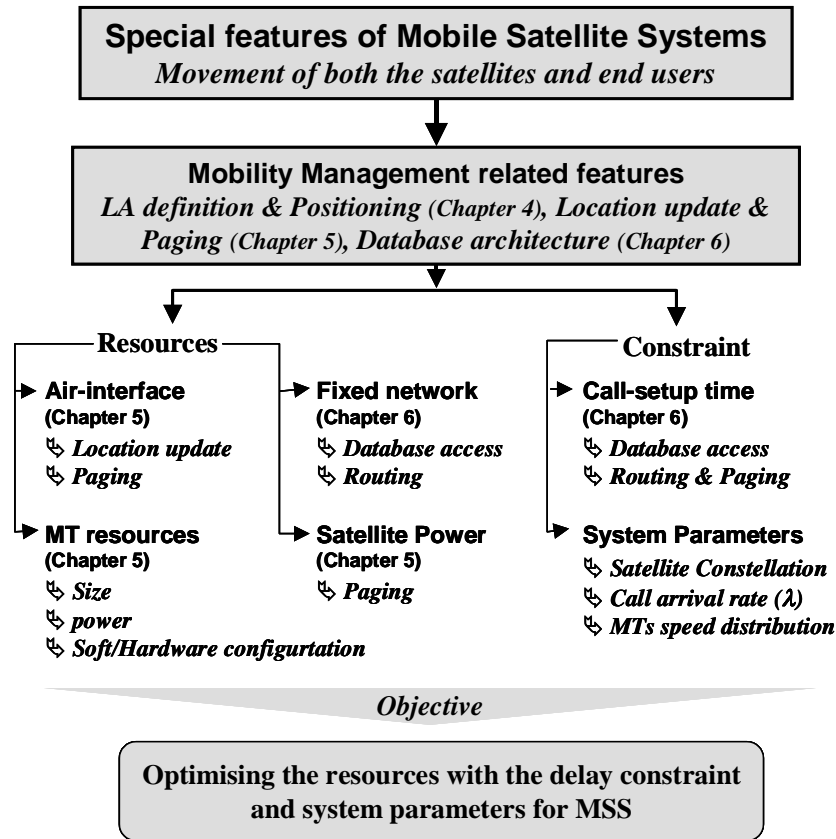


Figure 1-2: Outline of the research work

Based on the discussion so far, main research area selected for investigation in this thesis is the development of a location tracking scheme by optimising air-interface traffic, fixed network traffic, frequency of accessing databases, satellite power and terminal power with the constraint call set-up delay. The outline of the research work is shown in Figure 1-2. This thesis is divided into seven chapters. The next two chapters give the foundation for the research work, which is explained in chapter 4 to 6.

Chapter 2 gives details of satellite constellation characteristics and design techniques. Requirements of the satellite constellations for communication purposes and constraints involved in achieving the requirements are identified. The categorisation of different types of satellite orbits and patterns are addressed. Methods of selecting satellite constellations for specific scenarios are investigated with comparison.

Chapter 3 reviews the *1G*, *2G* and *3G* cellular systems and explains fundamentals of the *GSM* network architecture and signalling with different physical and functional entities. The mobile satellite system network architecture with additional functionalities is also introduced. The

mobility management techniques used in terrestrial systems are presented and the difficulties in using these techniques in *MSS* are identified. Existing mobility management techniques for *MSS* are also described as background.

Chapter 4 describes the existing methodologies for defining location area and positioning methods. New methods for defining location area and finding terminal positions are proposed and their effective implementation is evaluated.

Chapter 5 investigates *MM* signalling over the air-interface due to location tracking. The concept of intelligent paging is explained with an implementation method for *MSS*. Disadvantages of intelligent paging are identified and a new paging method is proposed as an improvement. Performance of different combinations of location update methods and paging methods are evaluated and a suitable combination is then proposed.

Chapter 6 deals with *MM* signalling in the fixed network. Signalling network architecture for *MSS* and a method of distributing the physical entities of the network architecture all over the globe are outlined. Using this network architecture layout, performance of different location tracking mechanisms on the fixed network are investigated to identify an optimised scheme based on the *call set-up delay*.

In chapter 7, conclusions are drawn and the future work is outlined.

1.3 Novel work resulting from this thesis

1. A new methodology for defining a fixed location area on the earth is proposed.
2. Two simple positioning methods for location tracking are proposed.
3. A method of implementing the virtual paging cell method is given.
4. A new paging method using footprint size beam is proposed to overcome the problems in implementing the intelligent paging scheme.
5. A full database architecture and layout for *MSS* are introduced.
6. A method of calculating optimal location area considering both air-interface signalling and fixed network signalling is introduced.
7. A simulation platform is developed to investigate different location tracking schemes in *MSS*.