Optimisation of Mobility Management for Mobile Satellite Systems Resources

by

Kanagasabapathy Narenthiran

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University of Surrey

Centre for Communication System Research
School of Electronic Engineering, Information Technology and Mathematics
University of Surrey
Guildford, Surrey GU2 7XH, UK

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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.

Email: K.Narenthiran@eim.surrey.ac.uk

WWW: http://www.ee.surrey.ac.uk/Personal/K.Narenthiran

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Glossary of Terms

1G - First generation mobile systems
2G - Second generation mobile systems
3G - Third generation mobile systems
3GPP - 3rd Generation Partnership Project
ACM - Address complete message (ISDN message)
AGCH - Access Grant Channel
AMPS - Advanced mobile phone system
AM - Amplitude modulation
AN - Access network
ANS - Answer message (ISDN message)
ATM - Asynchronous transfer mode
AuC - Authentication Centre
BCCH - Broadcast Control Channel
FCCH - Frequency Correction Channel
BCH - Broadcast Channels
BER - Bit error rate
BS - Base stations
BSC - Base station controller
BSIC - Base station identity code
BSS - Base station subsystems
BSSAP - *BS* subsystem application part
BSSMAP- *BSS* management application-process
BTS - Base station transceiver station
C/N - Carrier to noise ratio
CAR - Call arrival rate
CC - Call control
CCCH - Common control channel
CCH - Control channel
CCITT - International Telegraph and-Telephone Consultative Committee
CCSR - Centre for Communication System Research at UniS
CDMA - Code division multiple access
CM - Communication management
CN - Core network
DCCH - Dedicated control channel
DLA - Dynamic location area
DLL - Data link layer/Dynamic link-library
DLR - German Aerospace Centre
DSS1 - Digital subscriber signalling-system No.1
DTAP - Direct transfer application part
EC - Echo Canceller
EIR - Equipment Identity Register
EIRP - Equivalent isotropic radiated-power
ESA - European space agency
FACCH- Fast associated control channel
FBP - Footprint based paging
FDMA - Frequency division multiple access
FES - Fixed earth station
FLA - Fixed location area
FM - Frequency modulation
FN - Frame number
GCA - Guaranteed coverage area
GEO - Geostationary orbit
GMSC - Gateway mobile switching centre
GPS - Global positioning system
GSM - Global system for mobile
GUI - Graphic user interface
HAPS - High altitude platform
HCF - Highest common factor
HDLC - High-level data link control.
HEO - Highly elliptical orbit

HLR - Home Location Register
HPA - High power amplifier
IAM - Initial address message (ISDN message)
IBO - Input backoff
ICO - Intermediate circular orbit
ID - Identity
IMSI - International Mobile Station-Identity
IMT200- International mobile-telecommunication 2000
IN - Intelligent network
IP - Internet protocol
IS-95 - Interim standard-95
ISC - International switching centre
ISDN - Integrated services digital network
ITU-T - International Telecommunication-Union-Telecommunication-Standardization Bureau-
IWF - Interworking function
IWTF - Internet wireless task force
LA - Location area
LAC - Location area code
LAI - Location area identity
LAPD - Link access protocol for D-channel of *DSS1*
LAPDm- Modified version of the *LAPD*
LAR - Location area radius
LEO - Low earth orbit
LOS - Line of sight
*LST*P - Local signalling transfer point
LUR - Location update rate
MCC - Mobile country code
MEO - Medium earth orbit
MM - Mobility management
MNC - Mobile network code
MS - Mobile station
MSC - Mobile switching centre
MSISDN - Mobile station *ISDN* number
MSRN - Mobile Station Roaming Number
MSS - Mobile satellite system
MSSC - Mobile satellite switching centre
MT - Mobile terminal
MTP2 - Message transfer part level 2
NASA - National Aeronautics and Space - Administration
NCC - Network control centre
N-CDMA- Narrowband *CDMA*
NLOS - Non line of sight
NMS - Network management subsystem
NMT - Nordic mobile telephone
NSS - Network subsystem
OAM - Operation, Administration and - Maintenance
OMC - Operation and maintenance centre
OSI - Open Systems Interconnection
PA - Paging area
PAGCH- Paging and Access Grant Channel
PCH - Paging Channel
PCN - Personal communication network
PDC - Personal digital cellular
PDF - Probability density function
PES - Primary Earth Stations
PLMN - Public land mobile network
PM - Phase modulation
PRI - Pattern repetitive interval
PRM - Protocol reference model
PSTN - Public switched telephone network
PU - Pattern unit
QoS - Quality of service
QPSK - Quadrature phase shift key
RAAN - Right Angle of Ascending Node
RACH - Random access channel
RMSC - Remote mobile switching centre

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

Chapter 1

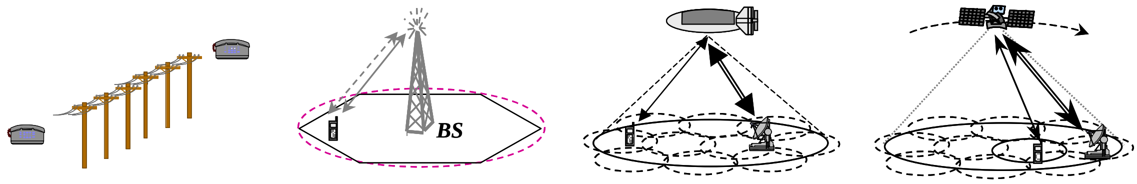
1 Introduction

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 21^{st} 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.



Fixed Network

- End terminals fixed
- High capacity with optical fiber
- Robust link

Terrestrial Mobile Network

- End terminals moving
- Capacity restricted by bandwidth
- Dynamically changing link
- Low path loss
- Shadowing from building and trees etc

High altitude platform Network

- End terminals moving
- Capacity restricted by bandwidth
- Dynamically changing link
- Moderate path loss
- Shadowing from building and trees etc.

Mobile Satellite Network

- End terminals moving
- Satellite moving (*LEO*/*MEO*)
- Capacity restricted by bandwidth & antenna/ power
- Dynamically changing link
- Expensive to launch
- Space junks at the end of life
- High path loss
- Shadowing from building and trees etc

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

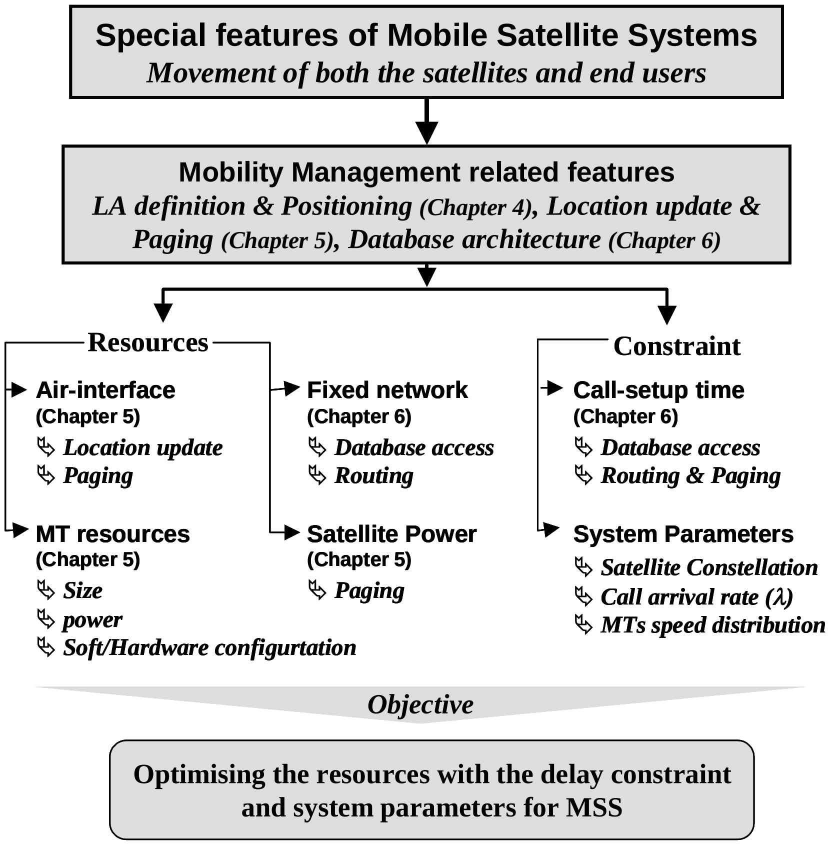


Figure 1-2: Outline of the research work

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*.