UNIVERSITI PUTRA MALAYSIA

COMPARATIVE ANALYSIS OF LOCATION MANAGEMENT SCHEMES IN WIRELESS ATM NETWORKS

UZMA USMANI

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By

UZMA USMANI

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To God and my parents…

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LRP	LOGICAL RADIO PORT
LS	LOCATION SERVER
MAC	MEDIUM ACCESS CONTROL
MAP	MOBILE APPLICATION PART
Mb/s	MEGA BITS PER SECOND
MT	MOBILE TERMINAL
NII	NATIONAL INFORMATION INFRASTRUCTURE
NNI	NETWORK TO NETWORK INTERFACE
OFDM	ORTHOGONAL FREQUENCY DIVISION MULTIPLEXING
PA	PAGING AREA
PCR	PEAK CELL RATE
PCS	PERSONAL COMMUNICATION SYSTEM
PHY	PHYSICAL
PNNI	PUBLIC NETWORK TO NETWORK INTERFACE
PSTN	PUBLIC SWITCHED TELEPHONE NETWORK
QAM	QUADRATURE AMPLITUDE MODULATION
QoS	QUALITY OF SERVICE
QPSK	QUADRATURE PHASE SHIFT KEYING
RAL	RADIO ACCESS LAYER
RP	RADIO PORTS
RSVP	RESOURCE RESERVATION PROTOCOL
SAAL	SIGNALLING AAL
SCR	SUSTAINABLE CELL RATE
SONET	SYNCHRONOUS OPTICAL NETWORK
SREJ	SELECTIVE REJECT
TA	TERMINAL ADAPTER
TAXI	TRANSPARENT ASYNCHRONOUS TRANSMITTER/RECEIVER INTERFACE
TBD	TO BE DETERMINED
TCP	TRANSPORT CONTROL PROTOCOL
TDMA	TIME DIVISION MULTIPLE ACCESS
TV	TELEVISION
UMTS	UNIVERSAL MOBILE TELECOMMUNICATIONS SYSTEM
UNI	USER NETWORK INTERFACE
UTP	UNSHIELDED TWISTED PAIR
VBR	VARIABLE BIT RATE
VBR-nrt	VARIABLE BIT RATE-NON REAL TIME
VBR-rt	VARIABLE BIT RATE-REAL TIME
VC	VIRTUAL CHANNEL
VCC	VIRTUAL CONTROL CHANNEL
VCI	VIRTUAL CHANNEL IDENTIFIER
VLS	VISITOR LOCATION SERVER
VPI	VIRTUAL PATH IDENTIFIER
VPN	VIRTUAL PRIVATE NETWORK
vUNI	VIRTUAL USER NETWORK INTERFACE
WAN	WIDE AREA NETWORK
WATM	WIRELESS ATM
WIMP	WIRELESS ATM INTERIM MOBILITY PROTOCOL

LIST OF ABBREVIATIONS

ABBREVIATION

AAL	ATM ADAPTATION LAYER
ABR	AVAILABLE BIT RATE
AESA	ATM END SYSTEM ADDRESS
ALT	ADAPTIVE LOCATION TRACKING
AMT	ADDRESSING MAPPING TABLE
AP	ACCESS POINT
API	APPLICATION PROGRAM INTERFACE
ARQ	AUTOMATIC REPEAT REQUEST
ATM	ASYNCHRONOUS TRANSFER MODE
AUS	AUTHENTICATION SERVER
B-ISUP	BROADBAND INTEGRATED SERVICES DIGITAL NETWORK USER PART
BS	BASE STATION
BT	BURST TOLERANCE
CATV	CABLE TELEVISION
CBR	CONSTANT BIT RATE
CDMA	CODE DIVISION MULTIPLE ACCESS
CDPD	CELLULAR DIGITAL PACKET DATA
CDV	CELL DELAY VARIATION
CLR	CELL LOSS RATIO
CS	CAPABILITY SET
CSIRO	THE COMMONWEALTH SCIENTIFIC AND INDUSTRIAL RESEARCH ORGANIZATION
CTD	CELL TRANSFER DELAY
DLA	DYNAMIC LOCATION AREA STRATEGY
DLC	DATA LINK CONTROL
EMAS	END-USER MOBILITY-SUPPORTING ATM SWITCHES
ETSI	EUROPEAN TELEPHONE STANDARDS INSTITUTE
FDMA	FREQUENCY DIVISION MULTIPLE ACCESS
FRC	FIXED REPORTING CENTER
FLA	FIXED LOCATION AREA
GSM	GLOBAL SYSTEM FOR MOBILE COMMUNICATION
HIPERLAN	HIGH PERFORMANCE LAN
HLS	HOME LOCATION SERVER
ID	IDENTIFIER
ILMI	INTERIM LOCAL MANAGEMENT INTERFACE
IMT2000	INTERNATIONAL MOBILE TELECOMMUNICATION SYSTEM 2000
IP	INTERNET PROTOCOL
IPX	INTERNETWORK PACKET EXCHANGE
IS-41	INTERMEDIATE SYSTEM
kb/s	KILO BITS PER SECOND
LA	LOCATION AREA
LAN	LOCAL AREA NETWORK
LCT	LOCATION CACHING TABLE
LM	LOCATION MANAGEMENT

LIST OF SYMBOLS

SYMBOL

η	Signalling cost per average page interarrival time
ρ	Mobility Index
τ	Update time for timer based location management strategy
$\alpha\ (K)$	Probability that there are K boundary crossings between two call arrivals
λ_p	Call Arrival Rate
Δt	Interarrival time of incoming calls
$1/\lambda_m$	Mean of cell residence time
A_c	Cell area
B_1	Location Area Boundary
B_2	Location Area Boundary
θ	Call-to-mobility ratio ($= \lambda_p/\lambda_m$)
D	Diffusion Constant
d	Update threshold for movement based update/paging
$F_m\ (s)$	Laplace-Stieltjes transform of cell residence time
$F_m\ (t)$	Cost of paging
$f_m\ (t)$	Cell residence time
K	Boundary crossings
L_{LA}	Optimal location area (LA) size
L_c	Cell Size
$N\ \{.\}$	Counting function that counts every cell contained in the paging area (PA)

P	Paging cost/signalling message
$p_b(t)$	Conditional location probability distribution
δ	Quantized location steps
t	Time
T	Mean First passage Time (MFPT)
T_r	Timeout Parameter
V	Variance of cell residence time
v	Drift velocity
x	Position of mobile

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By

UZMA USMANI

October 1999

Chairman : Associate Professor Borhanuddin Mohd. Ali, Ph.D.

Faculty : Engineering

Mobility is the cornerstone of wireless networks. Supporting mobility requires some form of tracking to locate mobile terminals within the network. In the wireline ATM network, the terminal is fixed and the terminal is located by identifying the terminal and following the routing information provided at each switch along the path. As terminals become mobile, the path to the mobile becomes dynamic; the terminal and the path are no longer synonymous. Signalling traffic incurred in tracking mobile users and delivering enhanced services causes an additional load in the Wireless ATM (WATM) network. Efficient database and location management schemes are needed to meet the challenges from high density and mobility of users, and various service scenarios.

In this thesis the three “natural” Location Management Strategies, i.e., Timer-Based, Location Area Based and Movement Based are studied and analysed for a WATM network. The model used for depicting user motion and call arrival is Brownian motion with drift process and Poisson arrival process, respectively.

The Timer-Based location management strategy is one in which the user updates its location periodically after an "optimum" interval of time. This optimum interval of time is based upon the user's mobility and call arrival characteristics and is therefore best suited for that particular mobile.

In the Adaptive Location Area Based strategy, the user updates its location on each LA boundary crossing. The size of the LA changes according to the user's mobility characteristics. The objective is to minimise the combined average signalling cost of both paging and registration for each individual mobile user such that the overall system-wide signalling cost for location tracking can be minimised.

In the Movement Based location update scheme a mobile terminal performs a location update when the number of movements since the last location registration equals a predefined value *d*. This value is called the location update movement threshold. When an incoming call arrives, the network pages the cells within a distance *d* from the last registered location of the called mobile terminal. The paging process terminates as soon as the mobile terminal is successfully found.

The three strategies are compared in terms of cost effectiveness and application simplicity. It is concluded that the optimum timer based strategy is the best choice for location update in a WATM Network among the three strategies. It is also the simplest to implement since the user only has to maintain a clock to measure the time since its last update and send an update when the time out occurs.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi sebahagian daripada keperluan ijazah Master Sains.

ANALISIS PERBANDINGAN SKEMA PENGURUSAN LOKASI DALAM RANGKAIAN TANPA WAYAR ATM

Oleh

UZMA USMANI

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Pengerusi : Profesor Madya Borhanuddin Mohd. Ali, Ph.D.

Fakulti : Kejuruteraan

Kebolehgerakan adalah asas rangkaian tanpa wayar. Untuk menyokong kebolehgerakan, pelbagai pengesanan diperlukan untuk mencari terminal bolehgerak dalam lingkungan rangkaian itu. Apabila terminal menjadi bolehgerak, haluan kepada bolehgerak menjadi dinamik, terminal dan haluan tidak lagi sinonimus. Trafik pengisyaratan yang digunakan dalam pengesanan kebolehgerakan pengguna dan pembekalan perkhidmatan tambahan menyebabkan lebih muatan dalam rangkaian tanpa wayar ATM. Pangkalan data dan pengurusan skema lokasi yang canggih diperlukan untuk menangani cabaran dari akibat kepadatan dan kebolehgerakan pengguna dan juga pelbagai senario perkhidmatan.

Dalam tesis ini, tiga strategi "semula jadi" pengurusan lokasi iaitu "Berdasarkan Masa", "Berdasarkan Kawasan Lokasi" dan "Berdasarkan Pergerakan" didalami dan dianalisis untuk rangkaian tanpa wayar ATM. Model yang kami gunakan untuk pergerakan pengguna dan ketibaan panggilan adalah pergerakan Brownian dengan proses yang lincah dan proses ketibaan Poisson, masing-masing.

Strategi pengurusan lokasi "Berdasarkan Masa" telah didalami di mana pengguna mengemaskini lokasinya pada setiap tempoh setelah jangka waktu yang optimum. Jangka waktu optimum ini adalah berdasarkan pergerakan pengguna dan ciri-ciri ketibaan panggilan dan oleh sebab itu ia hanya sesuai untuk terminal itu sahaja.

Dalam strategi "Berdasarkan Lokasi Kawasan Boleh Disesuaikan", pengguna mengemaskini lokasi pada setiap perlintasan lokasi. Saiz lokasi berubah mengikut ciri-ciri pergerakan pengguna. Objektifnya adalah untuk meminimumkan kos putara pengisyaratan untuk gabungan kedua-dua kelui dan aktiviti pendaftaran setiap pengguna kebolehgerakan supaya keseluruhan kos isyarat untuk mengesan lokasi boleh diminimumkan.

Dalam skema kemaskini lokasi "Berdasar Pergerakan", terminal bolehgerak melakukan kemaskini lokasi bila bilangan pergerakan semenjak pendaftaran lokasi terakhir adalah bersamaan dengan satu nilai telah didefinisikan, d. Nilai ini digelar sebagai ambang pergerakan kemaskini lokasi.

Tiga strategi tersebut dibanding berdasarkan keberkesanan kos dan kemudahan aplikasi. Antara tiga strategi tersebut, adalah disimpulkan bahawa strategi berorientasikan masa yan optimum merupakan pilihan terbaik bagi pengemaskinian lokasi di Rangkaian WATM. Ia juga merupakan cara paling mudah untuk diimplementasikan memandangkan pengguna hanya perlu mengekalkan jam untuk mengukur masa, bermula dari pengemaskinian terakhir dan menghantar satu kemaskini bila masa tamat berlaku.

CHAPTER I

INTRODUCTION

Background

Communication is “a process by which information is exchanged between individuals through a common system of symbols, signs, or behaviour”. Telecommunication is “communication at a distance”.

Within the last decade, the world of telecommunications has started to change at a rapid pace. Data traffic, where the information is transmitted in the form of packets and the flow of information is bursty rather than isochronous, now accounts for almost 250 Mbits/sec of the total traffic transmitted over the backbone telecommunication networks. In addition to data traffic, video traffic is made possible by low cost video digitising equipment which is also on the rise. An additional contributing factor to the change in telecommunications is the almost unlimited bandwidth provided by modern fibre optical transmission equipment. Asynchronous Transfer Mode (ATM) technology is proposed by the telecommunications industry to accommodate multiple traffic types in a very high-speed wireline network. Briefly, ATM is based on very fast (on the order of 2.5 Gbits/sec or higher) packet switching technology with 53 byte long packets called cells being transmitted through wireline networks running perhaps on fibre optical equipment. Due to the fixed packet size and the very fast packet switching, ATM meets very strict timing and delay requirements. This makes the transmission of time-sensitive traffic, such as voice, through the ATM network possible. Since ATM is based on packet switching, it also accommodates data traffic. ATM networks are designed to support multiple traffic types with different priorities and quality of service requirements. They are being deployed in the backbone networks presently and are expected to progress to the edge of the current telecommunications networks.

Wireless telecommunications networks have broken the tether to the wireline networks and allow users to be mobile but still maintain connectivity to their offices, homes, etc. The wireless networks are growing at a very rapid pace; Personal Handiphone Service (PHS) in Japan has taken on millions of subscribers till now. The GSM based cellular phones have been deployed in Europe, Asia, Australia and North America. Wireless network subscribers demand not only voice but also data connectivity to the wireline networks such as the Internet. Existing digital cellular networks cater mainly to voice subscribers and offer only limited data capabilities including some short messaging and data rates of the order of 14.4 Kbits/sec. Higher bit rate wireless technologies for data transmission have not gained wide-spread acceptance due to technical and connectivity limitations.

A Wireless ATM Network provides a natural wireless counterpart to the development of ATM based wireline networks by providing full support for multiple traffic types including voice and data traffic in a wireless environment. Although the procedures for establishing a wireless ATM network have not yet been standardised by ATM forum, Europe Telecommunication Standard Institute (ETSI), ITU or by The Institute of Electrical and Electronics Engineers (IEEE), they possibly will be by the end of year 1999.

The ATM protocol is intended for transmission over a reliable physical layer such as optical fibre, capable of handling high bandwidth requirements. Wireless links, on the other hand, have a limited amount of radio resources available to them (e.g., 2~20 Mbps). Signalling traffic incurred in tracking mobile users and delivering enhanced services causes an additional load on the Wireless ATM (WATM) network. Efficient database and location management schemes are needed to meet the challenges from high density and mobility of users, and various service scenarios.

Location Management Overview

Location management for mobility tracking involves two operations:

- Location Update
- Paging.

In the standby mode, a mobile terminal informs the system of its location. This is what is called location update. This information is stored in the system, which allows it to track the user's location, more or less accurately, in order to be able to find him, for example, in case of an incoming call. The paging process achieved by the system consists of sending paging messages in all cells where the mobile terminal is expected to be located.

Therefore, if the location update cost is high i.e., user location knowledge is accurate, the paging cost will be low i.e., paging messages will only be transmitted over a small area. If the update cost is low and thus the user location knowledge is fuzzy, the paging cost will be high i.e., paging messages will have to be transmitted over a wide area.

An efficient mobile location tracking strategy should minimise the combined cost of paging and location update and also utilise the minimum amount of bandwidth in locating a mobile unit.

Brief Overview of the three "natural" Location Management Strategies

In this thesis we study the three "natural" Location Management Strategies, i.e., Timer-Based [Rose, 95], Location Area (LA) Based [Lie, et al., 98] and Movement Based [Akyildiz, et al., 96], and analyse them for a WATM network.

The Timer-Based location management strategy is one in which the user updates his location periodically after an "optimum" interval of time. This optimum interval of time is based upon the user's mobility and call arrival characteristics and is therefore best suited for that particular mobile.

In the Adaptive Location Area Based strategy, the user updates his location on each LA boundary crossing. The size of the LA is "adaptive", i.e., it changes according to the user's mobility characteristics.

In the Movement Based strategy, the user keeps track of the number of cell boundary crossings and updates when the number exceeds a predefined value. This type of update is more useful to avoid the ping-ponging effect of a mobile across an LA Boundary since it does not require the mobile to update on every boundary crossing.

The following sections of this chapter summarise the objectives of this research and briefly describe the contents of each chapter in the thesis.

Research Objectives

- To study the mobility aspects of Wireless ATM LANs.
- To study the various Location Management schemes proposed for Personal Communication Systems and analyse them for Wireless ATM networks.
- To analyse the three "natural" location update/paging schemes and compare them in terms of cost effectiveness and application simplicity.
- To identify the most suitable Location update/paging scheme among the three natural schemes for a Wireless ATM LAN.

Thesis Organisation

Chapter I provides the background for the thesis, Location Management (LM) Overview, Brief Overview of the three natural LM Strategies, Objectives and the Thesis outline.

The first section of Chapter II makes a thorough review of the WATM networks and introduces the Basic System Model adopted for our analysis. The second section of the chapter discusses Location Management (LM) in WATM Networks, the Network Entities, LM Requirements, the Signalling and Control Messages involved in the LM process, Classification of LM schemes [Zervas, et al., 98] and a review of the location tracking and paging schemes that have been proposed.

The first section of Chapter III illustrates the model of user motion considered, the assumptions made during the study and an in-depth analysis of the three types of LM Strategies i.e., Timer-Based, Adaptive Location Area Based, and Movement Based. The next section of the chapter describes the Simulator, i.e., Matlab used for simulation of the LM Strategies in the WATM environment. Later the design methodology of the simulator is discussed.

The first section of Chapter IV gives the analytical as well as simulation results obtained after analysing the LM schemes and compares them according to the Total Signalling Cost involved in each. The next section of the chapter gives a brief discussion of the results obtained.

Chapter V concludes the results obtained in Chapter IV and gives a proposal for future work to be done in this area.

CHAPTER II

LITERATURE REVIEW

Wireless ATM Networks

Recent advances in the design and development of portable devices capable of wireless communications coupled with the development and deployment of Asynchronous Transfer Mode (ATM) has brought us to the beginning of a new era in networking. ATM is designed to support high-bandwidth multimedia applications, and to provide bandwidth on demand, traffic integration, cost effectiveness, and flexible data networking. Bearing in mind that networking applications are focussing on multimedia services and ubiquitous information access, intensified by the birth of the World Wide Web, ATM is viewed as a strong candidate for support of such services, which can be extended to portable devices using wireless technologies. We envision this ubiquitous connectivity and wireless access to multimedia information services becoming one of the major networking paradigms in the near future, a paradigm which is the goal of wireless ATM research in many industrial research laboratories and universities as well as the Wireless ATM Working group, which was formed by the ATM Forum Technical committee in 1996.

Before attempting to answer any approach to mobile and wireless ATM, one needs to answer what is the rationale of using mobile and wireless ATM, and what are the challenges in implementing it. These questions are interesting because of two reasons. First, ATM was designed for an environment where the hosts do not move and are connected to a switch via a relatively error free and high speed point-to-point wired link. It is not obvious what enhancements are needed for ATM to work well in a mobile and wireless setting. Second, there is the inevitable comparison with IP, instead of using ATM, in a mobile and wireless environment. Advocating mobile and wireless ATM, particularly when existing products such as wireless LANs and Cellular Digital Packet Data (CDPD) are IP based, naturally makes one a participant in the on-going serious ATM versus IP debate in the data networking community.

Rationale for using Wireless ATM

The rationale for using wireless and mobile ATM can be explored along two dimensions that distinguish ATM [Raychaudhuri, 94]: " cellification" and "QoS-specifiable VCs". By cellification we refer to the fact that ATM uses fixed and small sized cells (48 byte payload with 5 byte header). By QoS-specifiable VCs we refer to the use of switched virtual circuits whose service quality parameters are negotiated at set-up time by the end-points with the network, and the network goes through a process of admission control and resource allocation before the connection is set-up.

Superficially, cellification appears to be a complete disaster for wireless ATM with a terrible waste of bandwidth for the last hop due to the large ATM cell header relative to the cell body. The reality, however, is more subtle. First, the fine-grained multiplexing as provided by ATM cells is well suited to slow speed links because it leads to lower delay jitter and queuing delays. Second, wireless links