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Analytical Study of a Dual Pointer Based Strategy for Location Update Using Node B Sojourn Time in UMTS Networks

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ABSTRACT

This article describes how Universal Mobile Telecommunications System (UMTS) is a 3G cellular network standard that uses location update (LU) and location search (LS) for mobility management. LU requires update in two location registers (LRs) - home LR (HLR) and visiting LR (VLR) - where one HLR controls multiple VLRs. HLR updates (HLRUs) are costlier, and hence should be less frequent. To achieve it, VLRs maintain a forward pointer chain among themselves, instead of updating HLR. But a lengthy chain increases LS cost considerably. So, we propose to restrict the chain length to unity by introducing an additional backward pointer, and using the concept of root-VLR similar to the home agent concept of mobile IP. We derive a closed form solution to approximate the average HLRUs per call, and substantiate it by simulation in cases of both random and diurnal mobilities. Results reveal substantial reduction in HLRUs per call, even when call-to-mobility ratio is high. UMTS operators will find the analysis worth considering, while managing their 3G networks.

KEYWORDS

Dual Pointer, Location Search, Location Update, Mathematical Analysis, Mobility Management, Pointer Forwarding, Root-VLR, UMTS/3G

1. INTRODUCTION

Though fourth generation (4G) mobile services are emerging fast as the customers' preferred choice, Universal Mobile Telecommunications System (UMTS) (aka third generation (3G) mobile cellular network standard) is still the prevalent mode of mobile communication in most of the countries today. UMTS supports both voice calls and data services in mobile terminals (MTs) (EIA/TIA, 1991). Topologically speaking, in a typical UMTS network, the large service area is divided into several location areas (LAs) (Figure 1). Usually, each LA is quite big in area, covered by a single mobile switching centre (MSC) (Lin, Reducing Location Update Cost in a PCS Networks, 1997). But an LA can be smaller in size too, say the area under one radio network controller (RNC) as shown in Figure 1, provided the subscriber density be high in that region. In order to manage voice calls effectively, UMTS networks maintain two types of location registers (LRs), namely home LR (HLR) and visitor LR (VLR) (Lu, Shyn, & Wang, 2016), (Popal & Sharma, 2017), (Zhao, Liew, Zhang, & Yu, 2016). Typically, each MSC has an associated VLR (Figure 1) so that there are many VLRs normally in a UMTS network. However, usually, one HLR is maintained for each service area, and consequently, each HLR controls multiple VLRs.

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To track MTs, the UMTS network performs two well-known operations, viz. location search (LS) and location update (LU), utilizing the information already stored in HLR and VLR(s). Conventionally, the network follows the standard IS-41 protocol (EIA/TIA, 1991) to carry out location management in the following manner. Let us consider an MT (say MT_1) on the move. If it changes its LA without changing its MSC, only a VLR update (VLRU) happens for MT_1. However, if it changes MSC too, a VLR update happens as usual plus an additional HLR update (HLRU) happens i.e., its current LA address is updated in the VLR and its current VLR address is updated in the HLR. Telecom operators prefer to delay HLRU as late as possible because HLRU is much costlier than VLRU (Popal & Sharma, 2017), (Zhao, Liew, Zhang, & Yu, 2016), (Sadhukhan, Moitra, Venkateswaran, & Saha, December 2014), (Wang, Lei, Fan, & Hu, 2014) (Wang, Jiang, Yuan, & Ferng, 2014). So, every LU protocol must keep this mind, while planning location management.

Now, let us suppose that another MT (say MT_2) tries to call MT_1. At this point, LS for MT_1 will come into play. In fact, an LS process comprises two sequential sub-processes: (1) *pre-paging-probe* (PPP) and (2) actual *paging*. Taking cue from the HLR/VLR entries created by previous LUs, PPP zeroes in on the paging area (PA) (Wang, Lei, Fan, & Hu, 2014), (Wang, Jiang, Yuan, & Ferng, 2014), in which MT_1 is expected to reside currently. Then the actual *paging* happens for the whole PA to find out the MT_1. An LA may be divided into multiple PAs, or an LA may constitute a single PA depending on the subscriber concentration and the frequency of their incoming calls. In this paper, for our convenience in analysis, we consider PA and LA to be of the same size. Thus, in this work, PPP sub-process first narrows down on LA using both HLR and VLR entries of MT_1; then the UMTS network pages that particular LA for locating the exact Node B, wherein MT_1 is currently residing.

Location management in UMTS networks is a long-standing research arena full of publications (Xiao & Chen, 2006) (Zhao, Liew, Zhang, & Yu, 2016) (Popal & Sharma, 2017). These works are mainly of two types, namely dynamic and static. Three most common dynamic location management schemes are time-based, movement-based, and distance-based. On the other hand, static schemes include IS-41, pointer forwarding (Chen & Gu, 2003), hierarchical HLR (Jannink, Lam, Shivakumar, Widon, & Cox, 1997), and distributed HLR (Lin & Tsai, 1998). A static LU scheme such as IS-41 (EIA/TIA, 1991) is very attractive to the operators because of its simplicity in implementation. As long as an MT moves or resides within the same LA, no LU happens. Only when the MT crosses an LA boundary, its location information is updated in the VLR (and HLR, if necessary). On the contrary, in a dynamic LU, say in time-based LU, location information is updated periodically in the LRs, even if the MT does not change LA. Generally speaking, though dynamic schemes are more complex to implement, they perform better than static ones. In this work, however, we consider the hybrid strategy that combines time-based LU with pointer forwarding (Sadhukhan, Moitra, Venkateswaran, & Saha, December 2014). The time under consideration is Node B-sojourn-time, which is the time spent by an MT inside a Node B. So, in our scheme LU is not exactly periodic. Our pointer-based mechanism is an extension of the strategy stated in (Chen & Gu, 2003). It is called dual pointer scheme (DPS) because, unlike previous works that use only one forward pointer (we call it single pointer scheme (SPS) in this paper), it uses two pointers – one forward and one backward. DPS has not been explored much in the literature mainly due to the lack of supporting mathematical analyses, which we present in this work. This is the major contribution of this work. Though UMTS operators preferred DPS over SPS, absence of a closed form solution to calculate the average number of HLRUs in the DPS under various call-to-mobility (CMR) scenario was acting as a deterrent to them. They want to know also the performance of the scheme under diurnal mobility (Xiao & Chen, 2006), which is slowly becoming the order of the day. This paper addresses both the issues at length and provides encouraging results to the network operators.

The paper is organized as follows. Following introduction in Section 1, related works on IS-41 and pointer forwarding scheme are described in Section 2. Section 3 discusses the modified technique in detail in order to allow us mathematically analyse the HLRU process leading to a closed form solution in Section 4. Comparison with simulation results and the conclusions are given in Section 5.

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