Improving Quality of Experience of Subscribers through Post Deployment Network Planning in UMTS Cellular Networks

Samir K. Sadhukhan, Indian Institute of Management Calcutta, India
Swarup Mandal, Wipro Technologies, Kolkata, India

ABSTRACT

It is an established fact that cost of churning is a common concern for being profitable in the cellular network service provider’s space. Service providers can view this problem as a service management problem and can have a solution to enhance the stickiness of subscribers by managing the quality of user experience. Quality of Experience (QoE) is important in contrast to Quality of Service (QoS). Three basic components of service management are stage, prop, and user experience. In this cellular network service context, network infrastructure acts as prop. Prop needs to be flexible to enable the personalization in providing the service. In reality, the major challenge for a service provider is to keep the fitment between prop and the dynamic changes in subscriber profile in a cost effective manner. To define the problem more precisely, the authors take the conventional UMTS cellular network. Here, operators have considered single-homing of RNCs to MSCs/SGSNs (i.e., many-to-one mapping) with an objective to generate service at lower cost over a fixed period of time. However, a single-homing network does not remain cost-effective and flexible anymore when subscribers later begin to show specific inter-MSC/SGSN mobility patterns over time. This necessitates post-deployment topological extension of the network in which some specific RNCs are connected to two MSCs/SGSNs via direct links resulting in a more complex many-to-two mapping structure in parts of the network. The authors formulate the scenario as a combinatorial optimization problem and solve the NP-Complete problem using three meta-heuristic techniques, namely Simulated Annealing (SA), Tabu search (TS), and Ant colony optimization (ACO). They then compare these techniques with a novel optimal heuristic search method that the authors propose typically to solve the problem. The comparative results reveal that the search-based method is more efficient than meta-heuristic techniques in finding optimal solutions quickly.

Keywords: Ant Colony, Cellular Network, Dual-Homing, Heuristic Search, Network Planning, Optimization, Simulated Annealing, Tabu Search, Universal Mobile Telecommunication Service (UMTS)

1. INTRODUCTION

In the last few decades, the world has seen a quick transformation of cellular network service (CNS) with respect to a subscriber. In the beginning, we have seen a CNS was challenged to provide wide coverage which called for a good amount of investment on infrastructure. Following this challenge, CNS faced the challenge of retaining a subscriber profitably in a multi-operator regime. In the past, various
CNS adopted a strategy or a combination of them to address this retention problem. Some of these strategies are related to attractive pricing through share infrastructure, differentiated pricing thereby relating pricing with Quality of Service (QoS), subscriber loyalty program, etc. All of them are very short living in terms of giving an edge over competitors as they are readily copied. In addition to the above fact, cellular network service has been viewed now as a commodity service with a little differentiation from service providers. This made the problem of subscriber retention all the more challenging and complex. This problem of CNS can be viewed as a service management problem (Bisdikian et al., 2010) where key focus will be managing the experience of a subscriber whenever subscribers avail the service. Each experience of subscriber needs to be viewed as an opportunity to build the loyalty by using different emotional parameters of subscribers. So to a CNS, key parameter should be Quality of Experience (QoE) rather than the QoS. In this setting, cellular network service can be viewed as stage and network infrastructure should be viewed as a prop to generate a personalized service and thus to control the QoE. The prop should be flexible, reliable enough to capture the context of personalization and provide it consistently to build on the quality experience. Now CNS is to achieve this with a very competitive price of service while meeting various technology constraints like availability of spectrum. In this context the prop i.e., network infrastructure needs to be planned in such a manner so that it can adapt the changes in subscribers’ pool. This makes the post deployment networking (Sadhukhan et al., 2009) planning more important. The post deployment network planning can be done with respect to a parameter or a combination of parameters. In this work, we have taken “cost effective usage of control channel” which has an impact on the QoE in terms of call admission and supporting the call on the move as a parameter to optimize. We have taken cost of handoff as a proxy variable to the “usage of control channel” thus representative variable for QoE.

The dynamic nature of subscriber’s profile makes the operation of cellular networks suboptimal with the passage of time in terms of the handoff cost, and, hence, re-planning of networks needs to be done from time to time, with the existing deployment as a set of constraints (to protect investments). Post deployment planning plays a key role in optimizing the incremental capital investment. In this context the prop i.e., network infrastructure needs to be planned in such a manner so that it can adapt the changes in subscribers’ pool. This made the problem of subscriber retention all the more challenging and complex. This problem of CNS can be viewed as a service management problem (Bisdikian et al., 2010) where key focus will be managing the experience of a subscriber whenever subscribers avail the service. Each experience of subscriber needs to be viewed as an opportunity to build the loyalty by using different emotional parameters of subscribers. So to a CNS, key parameter should be Quality of Experience (QoE) rather than the QoS. In this setting, cellular network service can be viewed as stage and network infrastructure should be viewed as a prop to generate a personalized service and thus to control the QoE.

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In the post deployment planning phase an operator may encounter three possible scenarios (i) handoff traffic increases proportionately with the increase of network load, (ii) network load increases without increasing the handoff traffic, and (iii) network load does not increase while handoff traffic does. The first two cases usually occur when subscribers’ density increases permanently. This can be addressed in post deployment planning phase by splitting cells (where capital expenditure as well as handoff cost will increase) or by redefining the connectivity of cells and switches. The third case is very common which may arise due to a gradual change in mobility pattern of the existing subscriber base over a long period of time (Clayirci & Akyildiz, 2002). This problem can be addressed by regrouping cells into new clusters i.e., by changing the connectivity of NodeBs to RNCs and RNCs to MSCs/SGSNs (Quintero & Pierre, 2002; Pierre & Houeto 2002; Dialloetl, 2006; Amzallagetl, 2007). However, this cannot take care of situations where handoff increases due to periodic (temporal) changes of subscribers’ locations. If there is a clear pattern of this temporal mobility of subscribers, a multi-homing consideration (where a NodeB is connected to more than one RNC, and one RNC is connected to more than one MSC/SGSN) will be a useful strategy in post deployment tuning stage. Obviously, the multi-homing concept can be implemented at two levels, namely, in the first level, multi-homing of NodeBs, and, in the second level, multi-homing of RNCs. In this paper, we have considered dual-homing of RNCs, where some RNCs (to be decided optimally) are connected to...
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