Software Defined Networking to Improve Mobility Management Performance

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Design and Analysis of Communication Systems (DACS), University of Twente, The Netherlands
{m.karimzadeh,a.sperotto,a.pras}@utwente.nl

Abstract. In mobile networks, efficient IP mobility management is a crucial issue for the mobile users changing their mobility anchor points during handover. In this regard several mobility management methods have been proposed. However, those are insufficient for the future mobile Internet in terms of scalability and resource utilization as they mostly follow the centralized management approach owning several inherent restrictions. In this research a novel mobility management approach relying on the OpenFlow-based SDN architecture is proposed. Such an approach manages mobility in a scalable fashion while optimally utilizing the available resources. This approach is also appropriate for the cloud-based Long Term Evolution *(LTE)* system, in order to (i) keeping sessions active during handover, and (ii) providing traffic redirection when a virtual machine (*e.g.,* a mobility anchor point), migrates from one virtualization platform to another, while keeping the on-going sessions running, as well. This research is currently in its initial phase and is planned to eventuate as a Ph.D. thesis at the end of a four year period.

1 Introduction

Recently, Telecommunication networks (*e.g,* 3G and 4G cellular networks) and Mobile networks (*e.g,* WiMAX and WiFi) have increasingly become the major access method to the Internet and data services. Accordingly, many networks currently experience a rapid growth in the number of mobile subscribers and wireless data traffic. Over the last few years, wireless operators' networks have rapidly turned into full IP-based networks for both voice and data, thus stimulating an underlying IP mobility support. Mobility management refers to a set of mechanisms to keep ongoing-sessions continuity while a mobile user changes his/her physical channel, access network or communication protocol. Real-time IP multimedia applications such as Video Conferencing, Voice over IP (*VoIP*), Game net, download/upload of large size files (*particularly in cloud computing environment*) are examples of such notably demanded applications in mobile network environments, in which supporting IP mobility and seamless session continuity is a necessity for the users changing their mobility anchor points during inter-operator and intra-operator/technology handovers.

Various mobility management mechanisms may employ different layers of the OSI protocol stack to handle their functionalities [1]. In the physical layer, mobility management carries out the detach and attach operations to different access points during handover. In the network layer, mobility support means to deal with the change in the sub-network. Mobility support in this layer may be based on routing (used *e.g.,* in Cellular IP [2]) or mapping (used *e.g.,* in Mobile IP (*MIP*) [3] and Proxy Mobile IP (*PMIP*) [4]). In the transport layer, mobility management focuses on keeping the on-going TCP connection, though IP address is changing (used *e.g.,* in Mobile Stream Control Transmission Protocol (*M-SCTP*) [5]). In the application layer, a particular design is considered to tackle mobility issues for each application type (used *e.g.,* in the Session Initiation Protocol (*SIP*) [6]), or a middle ware may be implemented between applications of two nodes to manage mobility, such as WiSwitch [7]. The network layer based scheme is the most popular one offering transparent mobility support to all kinds of applications. MIP [3], PMIP [4], and 3GPP mobility management [8], are examples of such scheme.

Most of these solutions rely on a centralized mobility management entity which is in charge of both control and data planes [9],[4],[8]. Centralized mobility management inclines to several restrictions such as centralized management of one/several hierarchical tunnels for each Mobile Node *(MN)*, data processing overhead to perform encapsulations/de-capsulation functions during tunneling updates, network bottleneck, single point of failure and non optimal routing (*particularly when MN and correspondent node are close to each other but are both far from the mobility anchor point*) [10],[11],[12]. Centrally managed IP mobility in the current mobile Internet is not scalable enough to efficiently deal with demands raised by ever-growing number of mobile users of new generation of applications seeking for IP mobility.

Over the last few years, researches aiming to tackle limitations in centralized mobility management have been emerged. Double NAT (*D-NAT*) [13], Distributed Mobility Anchoring (*DMA*) [14], Inter-domain DMM, Local IP Access (*LIPA*)/Selected IP Traffic Offload (*SIPTO*) [15] are examples of such approaches. In this regard as discussed in [16] Software Defined Networking (*SDN*)/OpenFlow approach outperforms existing solutions.

SDN [17] has emerged as a new paradigm offering a logically centralized control model which detaches control and data planes, thus enabling direct programming of the control plane and abstracting the underlying infrastructure for applications and services. SDN makes networks programmable, manageable and adaptable to a wider extent, that is ideally suited for highly scalable mobile wireless networks.

OpenFlow [18], as the most common communication protocol used in SDN approach, can significantly facilitate traffic management by accessing the control plane and the data plane of switches and routers over the network (*e.g.,* Internet architecture). Capabilities offered by OpenFlow would be as an enabler to improve IP mobility management, such that each traffic path could be traced from an Internet Ingress node (*e.g.,* Internet PoPs) to an Egress node (*e.g.,* router at the edge of access network) as a separate flow, and traffic could be redirected to a new mobility anchor point without any IP address translation or modification. Consequently, it eliminates the need for IP and GPRS Tunneling Protocol (*GTP*) tunneling respectively in wireless and cellular networks demanded for mobility management and diminishes data processing and traffic overhead in a large scale as a result of optimum encapsulations/de-capsulation, handover and location signaling. Hereby it brings in more scalability with the increasing number of MNs.

Given that the OpenFlow-enabled switches and routers comprise a set of actions that give the possibility to modify the transiting packet headers belonging to a specific flow, as well as the ability of dynamic configuration of flow tables in switches and routers via OpenFlow Controller (*OC*), we believe the OpenFlow-based SDN architecture could be as a promising approach notably enhancing mobility management in terms of scalability and network resource utilization in the future mobile Internet.

The rest of the paper is organized as follows: in Section 2, we introduce our objective, detail the research questions, and describe the proposed approaches. Following Section 2, Section 3 outlines the sketched procedures to evaluate and validate the proposal. Finally in Section 4, we wrap up the paper.

2 The Objective, Research Questions and Approaches

The objective of this research is to answer the question ***"Could OpenFlow-based SDN architecture be used to improve mobility management and support session continuity accordingly?"***. In particular, our research addresses the following research questions:

1. *Is the current mobility management approach well-suited for the future mobile Internet?*
2. *How OpenFlow-based SDN architecture could be used to support session continuity?*
3. *Which OpenFlow-based SDN approach is better-fitted to support mobility management?*

The first question discovers the main constraints of utilizing the centralized mobility management approach in the future mobile Internet, and investigates the superseded mobility management scheme (*i.e.,* distributed mobility management) and compares it with the centralized one. Comprehensive literature review is the first step of the plan. Further, quantitative measurements and analysis of some relevant performance metrics (*e.g.,* resource utilization and delay), using NS3-LENA [19] simulation environment will be carried out, complementing the comparison. As network and traffic data utilized in the simulation environment always have deviations from real ones, real-world measurements are thought of as further evaluation, if possible.

By question 2, we figure out how capabilities of OpenFlow-based SDN architecture [17],[18] could be utilized to enable and further enhance mobility management. OpenFlow-enabled switches are augmented with a set of actions that could be applied to flow-specific packets providing further capabilities [18].

Set-Field, as the most relevant one for our purpose, provides the possibility to OpenFlow switches to modify packets' and frames' headers. A combination of *Set-Field* and *Output* (*identifying the output interface*) actions, could be used to provide dynamic per-flow forwarding and redirection. Flow tables and action lists in OpenFlow-enabled switches are added and modified by the OC utilizing dedicated secure connections.

Further, in order to find out which mobility management network structure could be better-fitted to the next generation mobile networks, we will benefit from [20],[21], which extend current IP mobility solutions for flat architectures and describe the requirements for distributed management based on IPv6 networks. In the distributed framework, the data plane *(partially distributed)* or both the data plane and control plane *(fully distributed)* are distributed among the mobility anchors located at different network segments *(usually at the edge of the access network)*, and MNs are served by a closer anchor entity accordingly.

Answering question 3, we investigate which of the full or partial OpenFlow approaches is better-suited to be integrated to the operator's transport network to fulfill session continuity requirements and support mobility management functionality. In the first approach, all routers in the transport network are OpenFlow-enabled and no modification of the packets is needed for traffic redirection. Whereas, in the partial approach, only the routers placed at the edges of the transport network are OpenFlow-enabled and traffic redirection on the transport network is based on layer 3 routing instead of flow forwarding. In this approach packets' headers must be modified at the edge of the transport network (at the Ingress and Egress switches).

3 Evaluation and Validation

In line with question 3, the proposed solutions, will be evaluated based on different sets of experiments implemented within the NS3-LENA simulation environment and various predefined metrics (*e.g,* scalability, signaling overhead, etc.) will be measured and analyzed. Further, within the context of the Mobile Cloud Networking (*MCN*) project [22], we intend to implement a prototype of the proposed OpenFlow-based SDN architecture in OpenStack [23] virtualization test bed as a supplementary validation.

4 Final Considerations

The main objective of this research, will be achieved within a period of four year, as part of a Ph.D thesis. This research has been funded by the EU FP7 MCN project (#318109) and EU FP7 Flamingo Network of Excellence (ICT-318488).

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