Developing an Application Based on OpenFlow to Enhance Mobile IP Networks

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***Abstract*—Mobile Internet Protocol (IP) has been developed to maintain permanent IP addresses for mobile users while they are moving from one point to another where the Mobile Terminal (MT) device will have two IP addresses: a static *home address* and a *care-of address* which will be changed and re-attached at each point of the movement of the MT. However, a location update message is required to be sent to the home agent for each new connection. This will potentially increase the handoff latency and leads to high load on the global Internet. This paper presents the concepts and the challenges of Mobile IP networks and then proposes the use of OpenFlow approach as an alternate transport mechanism to perform routing and to provide network connectivity for Mobile IP networks. The proposed application determines calculations and reroutes the subsequent packets. OpenFlow aims to optimize routing path and handoff performance by using controller's application and exchanges controllers' information.**

***Index Terms*—Mobile IP; OpenFlow; Network Mobility; Software Defined Networking; Next Generation Networks.**

I. INTRODUCTION

Due the increase of connected mobile nodes, next generation networks will be heterogeneous networks [1 - 2] and will require scalable and maintainable connections for ever changing environment. These connections need to ensure that mobile devices can be always connected to the network even when they are moving from one place to another, by establishing new connection links and replacing previous links. For these reasons, Mobile Internet Protocol (IP) has been developed as a solution of moving devices and to provide better experience services, using an alternative IP address that offers a short routing path.

However, one fundamental concept of Mobile IP is that the Mobile Terminal (MT) device needs to be always attached to its home network, which is considered as a limitation of the Mobile IP approach. Therefore, when the mobile device moves to another network, it can cause a number of challenges such as security, triangular connection, and handoff latency [3]. For example, when using tunneling, in case if that tunnel is broken, the transmission of packets could go to a malicious node. In addition, the Mobile IP routes the packets to the home network every time. This will cause load traffic and select unsuitable routing path. Moreover, the Mobile IP considers the distance between home agent and the foreign agent which cause handoff latency [4]. Some one can argue that, if the mobile node travels from home network to a foreign network, which is located just near to the sender, the Mobile IP needs to use a triangle routing path.

OpenFlow is an emerging network paradigm which decouples the control path from the data path of forwarding elements. Using this strategy, OpenFlow allows network element devices such as routers and switches to be programmable via a standardized interface [5]. In addition, OpenFlow provides high flexibility of novel packet forwarding and routing of network flows that can be adapted to the ever changing environment by using virtualization and flow-based routing.

Previous issues are surrounding the mobile nodes and the Mobile IP is insufficient for long/short connection with mobile device for appropriate transmission of flows. Therefore, this paper introduces OpenFlow as a base to support alternative IP address for mobile node. OpenFlow can manage the security of transition process and can manage authentication of users. In addition, OpenFlow can optimize the routing process, where it can deliver the packets directly to a certain OpenFlow switch which hold the mobile node. The correspondent node does not require a detour by passing the home network anymore. Using OpenFlow allows the constructing of flow entries within OpenFlow switch to update the new address of the mobile node. Thus, when the source has packets that need to be sent to a mobile node, the controller knows how to update, convert and then send that packets with the best routing path.

This article follows the logical outline indicated as following. Section II presents the overview of Mobile IP protocol. In Section III, the limitations of Mobile IP are described. Section IV addresses the main factors that influence the need of OpenFlow as a base for Mobile IP. In Section V, the implementation of OpenFlow based for Mobile IP is proposed. Finally, Section VI summarizes and concludes the paper.

II. MOBILE IP

With the rapid growth of wireless communications and the increase of market demands, it is inevitable to develop and introduce the Mobile IP technology. Mobile IP enables a

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mobile node to maintain active connections with the same IP address when it traverses from one point to another in the Internet. It adopts the traditional IP protocol to efficiently implement the communications for the mobile nodes [6 - 9]. It is necessary to frame the discussion with few terminologies in order to understand the operation of Mobile IP. According to the mobile IP specification, it introduces the following new functional entities:

Mobile node: This device is typically a standard host or router that moves its connectivity place among networks. The mobile node can change the location without changing its origin home IP address or may also seamlessly use its own constant IP address to communicate to other nodes.

Home address: This Is an IP address that allocates an extended period of time for a mobile node. This address will not be changed even if that mobile node have moved or connected to other foreign network.

Home agent: Basically a router on a mobile node's home network that operates tunneling of datagrams for delivery to the mobile node when it is away from home. The home agent will also maintain current location information for each mobile node.

Home network: This may be a virtual network that has a network prefix matching the one of a mobile node's home address. The mechanism of standard IP routing will transmit datagrams destined to a mobile node's Home Address to the mobile node's Home Network.

Foreign agent: This is a router on a mobile node's visited network that cooperates with the Home Agent in order to complete the datagram transmissions to the mobile node while it is away from Home network.

Foreign network: Can be any network in the Internet other than Home Network of the mobile node.

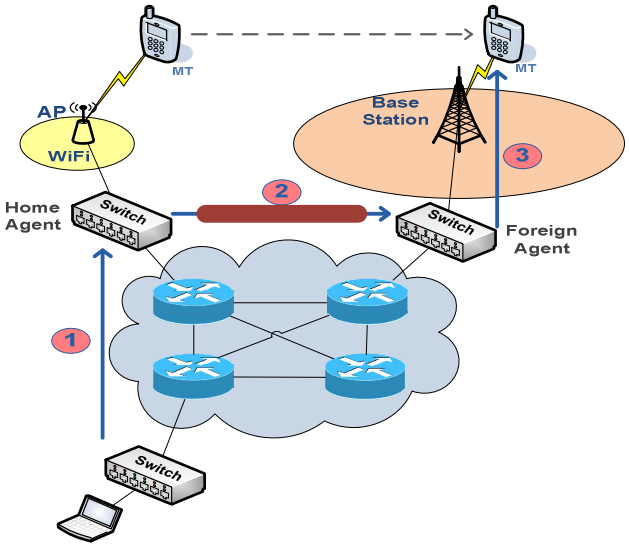

Fig. 1. Mobile IP Scenario.

Care-of address: The end point of a tunnel toward a mobile node, for transmitting datagrams to the mobile node when it is away from home. Care-of address can be used in two different types. Firstly, foreign agent care-of address is the address of the foreign agent in which the mobile node is registered. Secondly, co-located care-of address is a local address that the mobile node has connected with one of its own network interfaces which can be externally obtained.

Correspondent node: Another peer device that a mobile node is communicating with. This correspondent node can also be either stationary or mobile.

Tunnel: This is a path of network communications used to deliver datagram while it is encapsulated. In addition, the datagrams are routed while encapsulation to a knowledgeable agent, which will de-capsulate those datagrams and then forwards them along to its final destination.

Figure 1 demonstrates a scenario on how Mobile IP can cope with such dynamic IP addresses. A mobile node will belong to a specific network so called ***home network***. It has a static IP address on that network define as its ***home address***. Whenever a mobile node traverses to another connection point that belongs to a different network, that network is considered as a ***foreign network***. After the mobile node is reconnected, it needs to be registered to a network node. This node is usually a standard router on the foreign network known as a *foreign agent*. Then the mobile node will communicate with another agent called ***home agent*** on the user's home network and provides the home agent a ***care-of address*** of that mobile node. This address determines the foreign agent's location.

The following steps will illustrate the process of exchanging IP datagrams over a connection between mobile node and another peer device (Correspondent Node**)**. Refer to Figure 1 to help envision the roles of different entities.

1. CN transmits an IP datagram to the destination of mobile node (MT), with MT's home address in the IP header. IP datagram is routed to MT's home network.
2. The home agent will intercept the incoming IP datagram at home network, encapsulate it inside a new IP datagram that has the MT's care-of address in the header, and then retransmits the datagram. **Tunneling** is used where the outer IP datagram is given with a different destination IP. Finally, this IP datagram is routed to the foreign agent.
3. Foreign agent will then takes off the outer IP header, encapsulates the original IP datagram, and transmits it to MT across the foreign network.
4. When MT forwards traffic back to CN, it will use CN's IP address. In this case is a fixed address as CN is not a mobile node. MT will forward each IP datagram to a router on the foreign network for routing to CN.
5. MT forwards the IP datagram to CN will travel directly across the Internet to CN, using CN's IP address.

Mobile IP can be thought of as a way of performing three related functions. Firstly, there is an agent discovery mechanism known as **Discovery**, where mobile nodes can identify their prospective *home agents* and *foreign agents* as they move from point to point across the Internet. Secondly, a **Registration** process authenticated by the mobile node is used to inform its home agent of its *care-of address*. Thirdly, Mobile IP defines a simple mechanism called **Tunneling** to deliver

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datagrams to the mobile node when it belongs to a different network other than home. A home address uses Tunneling to forward IP datagrams to a care-of address [10 - 11].

III. Mobile IP Challenges

Mobile IP provides capability of changing the network attachment of the users without losing their connection while users moving. However, there are some issues should be considered to enhance services. These issues are presented in this section as following:

A. Security issues

Security is considered as a main challenging process with in Mobile IP network. The mobility of communication devices and wireless channel introduce some security issues. Security issues for Mobile IP are considered when the mobile device registers a new care-of address of a foreign agent to a home agent, this registration messages requires an authentication to improve the security performance [12 - 13]. Then, after registration some one can attack the session to transfer the data to a malicious node.

B. Triangle routing issues

Mobile IP scheme is based on triangle routing, where corresponding node sends packet to the mobile node's home network. Then, if the device moves to foreign network, the home agent sends packets to the foreign agent using IP-IP tunnelling [14]. After that the mobile node can send packets to the corresponding node without return packets to the home agent. The IP-IP tunnelling between home and foreign agent can cause long time delay and unnecessary network congestion. In addition, the tunnelling will consume an extra bandwidth, from the home agent to the foreign agent (care-of address) [15].

C. Handoff issues

Handoffs usually cause packets loss, especially with applications such as video streaming it is harmful. Whereas, the home agent is responsible of handoff, it makes huge traffic between the mobile device and the home agent, which lead to network congestion. Moreover, simultaneous handoffs for number of mobile nodes within wide area networks WAN can result network congestion [16].

IV. The Need For OpenFlow-Based Mobile IP

As Mobile IP has some limitations mentioned above, and therefore one can argue that it cannot be feasible. The main factors that impact to the implementation of mobile IP based on OpenFlow networks are discussed in this section.

A. Mobility support

Global forecast for total mobile devices released February 2012 can be seen in figure 2. Mobile devices are predicted to increase from 1.03 billion in 2011, or 10.1 percent of total fixed mobile devices, to 7.6 billion by the year 2016. This trend of mobility communications motivate to create new protocols as well as increased the needs for mobility support. As a result, it would be one of the promising reasons to implement Mobile IP based on OpenFlow networks.

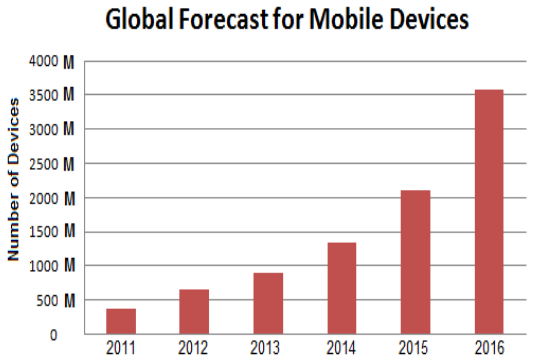

Fig. 2. Global forecast for mobile devices. Data presented from Ref [17].

B. Alternative technologies

In Mobile IP, a mobile device can presence itself after moving, by registering on foreign agent as a new location (care-of address). While the foreign agent inform the home agent of mobile device and new care-of address, to let home agent to prepare for setup the tunnel between home and foreign agent [18].

One possible alternative is that Mobile IP based OpenFlow can compute the best routes without tunnelling process. The controller will calculate and install the flow tables' entries for new destination address with careless of its point of attachment. For example, packet moves from Flow Table 1 to Flow Table 4 directly (see Figure 3). This would turn out to be a compelling technique for seamless mobility services to end-users.

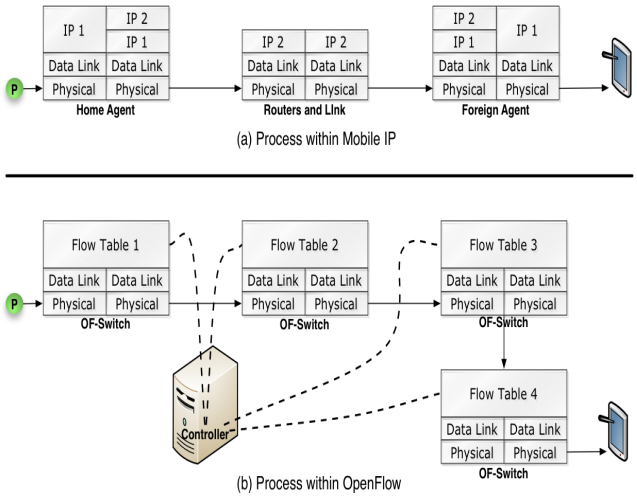

Fig. 3. Comparison of traditional Mobile IP and proposed OpenFlow based for Mobile IP.

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C. Improved Handoffs process

Currently, handover between different wireless technologies is hard to manage. This is because the intermediate links between the core networks are different, as they are built around a single wireless technology. By deploying OpenFlow based Mobile IP, Figure 3 shows that handover process can be achieved in a simple way of local registration to the new OpenFlow switch, which informs the controller regarding new location. OpenFlow based for Mobile IP can provide a simple hand-off solution that will allow mobile nodes to move within home network or foreign network seamlessly as a one larger network, without losing connection.

V. Mobile IP Based on OpenFlow Implementation

In regards to technologically optimization, OpenFlow based Mobile IP will require minor modifications of the operating systems in the correspondent node and will also be feasible with Layer 2 switching suite and specifications. The proposed development of Mobile IP based on OpenFlow networks is introduced in this section.

A. Registration process

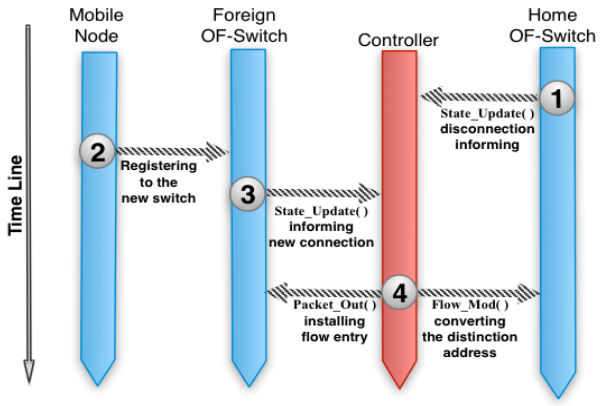

Fig. 4. Exchanging messages over the time.

OpenFlow-based Mobile IP can provide minimal overhead in terms of delivering the data and signalling information as well as effective routing scheme. The mobile node uses a direct route to communicate with the correspondent node. Moreover, the handoffs process will be performed with a lower packet loss rate due to the localized handling of the handoffs are performed somewhat faster as the network delay between mobile node and home switch does not affect the handoff.

Deploying Mobile IP in OpenFlow networks can enhance the mobility of mobile nodes where routing optimization and the high level decision making are performed by the controller. Moreover, Home agent and Foreign agent will be replaced by OpenFlow controller application. In Mobile IP, the mobile node will receive all the packets that must pass through the home agent, however, this route may not be the best.

In OpenFlow based Mobile IP, after mobile node moves from Home switch to the Foreign switch, according to Figure 4, it registers to the new switch basically Foreign switch. Then both Home and Foreign switch notifies the controller, using **State_Update()**, for new information regarding disconnection and reconnection. After that, the controller is able to calculate and install new flow entries in both switches. The controller uses **Flow_Mod(),** to modify the flow entry and convert the destination IP for Home switch. Also, the controller uses **Packet_Out()** for Foreign switch to guide the packet to reach its destination mobile node. In addition, each switch of OpenFlow is responsible for informing the controller, every time a mobile node moves. The Foreign switch informs for new connection and the Home switch updates for disconnection.

B. Packet processing

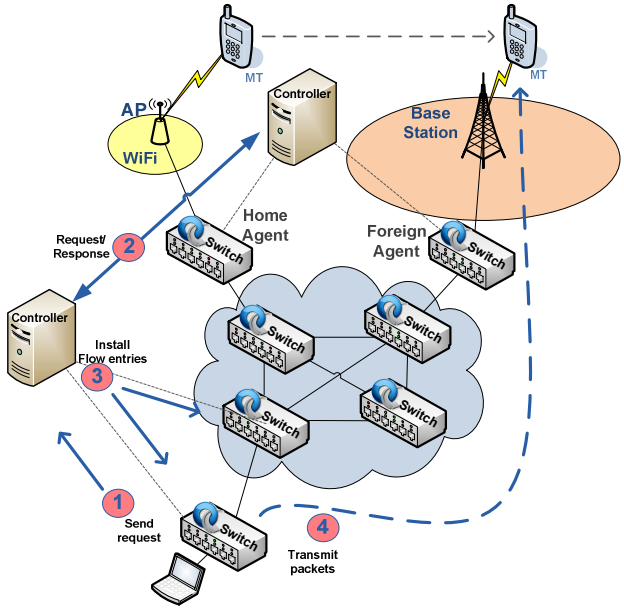

Fig. 5. OpenFlow base for Mobile IP scenarios.

Figure 5 illustrates the corresponding packet processes after the mobile node moves. Firstly, the CN sends the subsequence packet to the attached switch where the mobile node has been moved as shown in Figure 4. The controller which manages the CN's switch receives a request. Then the controller will check its library looking for the IP address of the mobile node. After that, the controller sends and receives new information from the other controller which manages the Foreign switch. Therefore, the controller now can update all the corresponding switches and the packets will be transmitted to the destination. In more details, the CN's controller will compute the new destination address and installs flows to the Foreign switch for the transparent transmission.

The information will be transmitted through a definite port number using a secure TLS channel. If the mobile node moves again, the previous Foreign switch will transfer the updated information to the controller to ensure that the packets are transferred to the new Foreign switch.

Meanwhile the controller will also update the information and again install flows to this new Foreign switch so the subsequent packets will be transferred directly from the correspondent node. This method of delivering packets to mobile node within OpenFlow switches can significantly

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improve the handoff performance and reduce the time delay for re-registration as well as solving the problems of triangle routing.

C. Mobile IP's Controllers Application

The Mobile IP's controller application is presented below with the details on the algorithm of this application. The OpenFlow controller is enhanced to calculate and install the flow entries for all corresponding OpenFlow switches. For Home switch, it converts the destination IP and installs the flow entries along to chosen path until it reaches the last care-of address. Meanwhile Foreign switch is responsible for informing and updating the controller for registration of the mobile node.

Algorithm 1 Mobile IP's Controllers Algorithm

```
# MT Re-registration
if MT moves to Foreign OpenFlow switch
    send registration request to Foreign OpenFlow switch;
    inform correspondent controller MT's care-of address;
    update controller's flow table;
end if

# Packet Processing (sent by OpenFlow switch)
for all p (where p is packet request sent by
OpenFlow switch to the controller)
  if packet is transmitted to a destination that belong to
    another controller
      send request to the destination's controller;
      calculate path to last care-of address;
      create flow entries in original's controller;
      install flow entries to chosen path switches by
          original controller;
      create flow entries in destination's controller;
      install flow entries to chosen path switches within
          destination's controller;
  else
      check the destination's care-of address;
      create flow entries;
      install flow entries to chosen path switches;
  end if
    end for
```

VI. Conclusion

There is an increase demand of Mobile IP over the past few years. This paper discusses most of the fundamental features of mobile IP where an extension standard protocol to IP is developed to allow mobile nodes to move seamlessly between different places on the network. Then, the paper discusses the needs for a successful implementation of Mobile IP. In this regard, we propose OpenFlow networks as an alternative technology to develop Mobile IP with the hope to address the current presented in the Mobile IP approach. By using OpenFlow based Mobile IP, routing of packets and handover performance are optimized by the controllers' application. This will improve mobile users experience while maintaining seamless pervasive connectivity. Future work can be an implementation of the designed algorithm and a run of experiments using Omnet++, focusing on wireless mobile applications.

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