2018 17th International Symposium on Distributed Computing and Applications for Business Engineering and Science

Design, Implementation and Verification of an UMIP based Multihomed Mobile Network Framework

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***Abstract*—The new generation of broadband cellular network technology together with WiFi makes the high-quality networking dependent services such as video streaming available on mobile devices. However, the leverage and handover in application layer among heterogeneous wireless networks still lacks of practical solutions. With the help of UDP based mobile IP protocol, this paper proposed a framework to allow a mobile device to work under cellular as well as WiFi network simultaneously, i.e., enabling the functionality of multihoming on this device. By a demonstration with a video application on an Android phone with dual networking interfaces, the feasibility and availability of our proposed multihoming framework are well proved. The framework has also been proved to be applicable in other scenarios such as seamless mobile handover.**

***Keywords*-Multihoming; Handover; Mobile IP (MIP)**

I. Introduction

Internet use continues shift from desktop to mobile in recent years and the trend seems never stop, the ability of providing the same or even higher level of service on mobile devices become more critical than before. However, on a typical mobile device such as smart phone, the Ethernet interface on a desktop has been replaced by a cellular or WiFi, the networking availability and performance become a big challenge. This paper proposed a solution to address two problems: i) maximizing the networking bandwidth; ii) providing the consistent and unstopped networking connection.

A mobile device usually requires to switch between WiFi and cellular network, the problem such as how to maintain the connectivity during a handover becomes a hot research topic. Another more challenging problem is the possibility to utilize the bandwidth from WiFi and cellular network simultaneously. Since most mobile applications build their service on top of TCP/IP, which means they rely on the IP address to communicate with their peers. However, the change of a device's underlying network cannot avoid to bring a new IP address, in this case, the continuity in the application layers is hardly maintained.

Mobile IP (or MIP) is an Internet Engineering Task Force (IETF) standard communications protocol which is designed to enable mobile device users to move among different networks while maintaining a same IP address. By introducing a Home Agent (HA), all the communications between a mobile node (MN) and its corresponding host will be relayed via the HA. This paper proposed a mechanism to enable an UMIP based Multihomed Mobile Network (UM^{3}N) Framework by establishing a tunnel between MN and HA. This tunnel will bind all available interfaces to support the seamless packets transmission on multiple interfaces, i.e., enabling the multihoming functionality on the MN.

II. Related Work

MIP provides an option to send packets to multiple care-of addresses for an MH. At the HA, the packets are duplicated and each registered care-of address will receive one copy. This approach decreases the number of dropouts in handover. However, it cannot decide which connection should be used and thus the networking bandwidth are wasted [1], [2], [3]. To support multiple Care-of Addresses (CoAs) or even multiple home agents, mobile IP (RFC 3775) and Network Mobility (NEMO; RFC 3963) also require some modifications [4]. In recent years more research shifts their focuses from IPv4 to IPv6 but the framework still remains the same as previous works on IPv4 [5].

Some multihoming research works aim to use the best available connections rather than maximize the total bandwidths of a mobile device, which means these solutions focus on seamless handover rather than maintaining multiple connections simultaneously. Another drawback of these two solutions is that they are transport layer approach ($pTCP$ in [6] and Stream Control Transmission Protocol (SCTP) in [7]), which leads other existing transport layer protocols such as TCP and UDP cannot take advantage of them. The solution proposed in this paper covers both goals: the communications will be delivered via all available interfaces but still be able to survive even with only one interface.

Multipath TCP (MPTCP) is another option to allow a TCP connection to use multiple paths to maximize resource usage and increase redundancy [8], [9]. These solution based on Multipath address some SCTP problems such as stringent quality of service (QoS) requirements and path asymmetry in heterogeneous wireless networks, but the issue that they cannot work well with the current TCP/IP based applications still remains.

In this paper, a simple but very practical multihoming solution is proposed and verified. The solution builds on top of MIP but does not rely on the multiple care-of addresses. It utilizes the network tunnel to simulate a

978-1-5386-7445-1/18/$31.00 ©2018 IEEE
DOI 10.1109/DCABES.2018.00019

network layer device and it operates with the current IP based applications.

III. Design

The original goal of MIP is to maintain the TCP connection between a remote host and a moving mobile device without having to change the TCP/IP. Figure. 1 illustrates a generic framework of a mobile IP network which usually contains three components: i) mobile node (MN); home agent (HA); and iii) foreign agent (FA). When MH is in its home network, the normal IP routing is performed between MH and the remote host: the outgoing packets are sent to the remote server via HA. Once a MN move out of its home network, HA will keep track of MH's care-of-address which represents the MH's new location. From the view of the remote host, he has no idea that the MH has moved to another network and its IP address has been changed. The remote host still intends to send packets to MH with HA's IP address as its destination address. The HA will redirect these packets to the MN through an IP tunnel between HA and FA. Thus the connection between MN and remote host is maintained, the movements of MN will not affect the running applications.

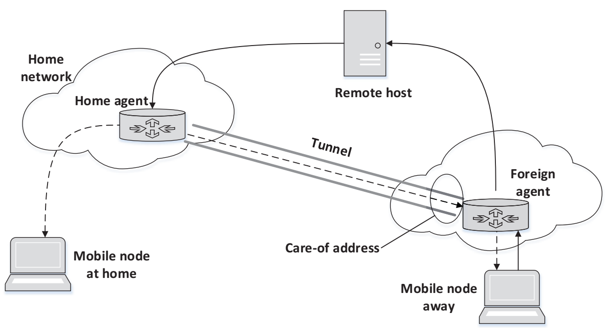

Figure 1. Mobile IP Generic Framework

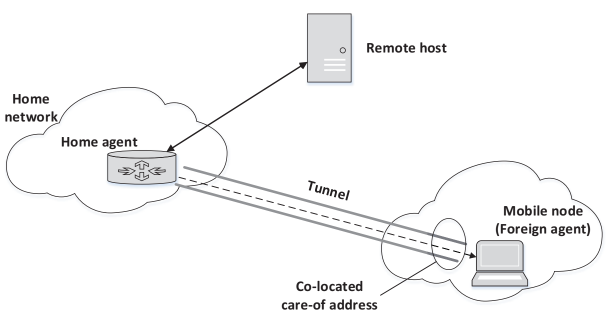

Figure 2. Mobile IP - Colocated Care of Address

If a MN also bears the functionality of a FA (they sit together), the care-of address is called a co-located care-of address. Thus the tunnel will be built directly between the HA and MN without the involvement of a separate FA. The situation is depicted in the Fig. 2 in which the HA becomes the permanent agent between a MN and a remote host. As long as the tunnel is maintained, the change of the actual communication interfaces of the MN will not be perceived by the remote host. Inspired by this idea, we proposed a multihomed mobile network framework based on an MIP with colocated care-of address. The design of UM^{3}N framework is depicted in Fig. 3.

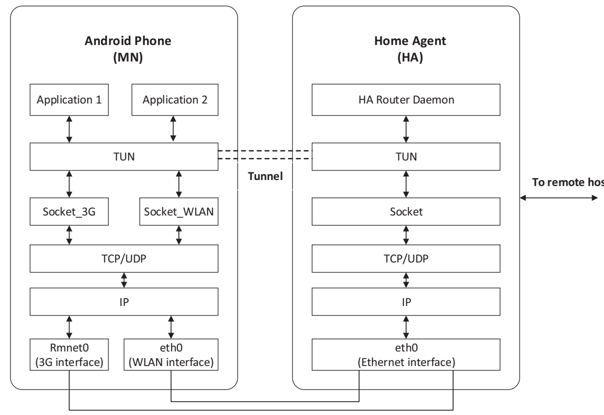

Figure 3. High Level Design of UM^{3}N Framework

In this design, an Android phone is used to represent the MN because Android is open source and easily customized on system level. In MN and HA, the IP packets are transmitted via a virtual tunnel (TUN) interface rather than directly on physical network interface(s). TUN simulates a IP layer device and operates with raw IP packets. A normal TUN runs in Linux user space and receives/sends packets from/to kernel for further processing (encapsulating IP packets to Ethernet frames and then transmitting via the physical network interfaces).

To support multihoming, the channel connecting TUN and the default physical interface is "hijacked". Two sockets ("Socket_3G" stands for cellular interface and "Socket_WLAN" for WLAN interface) are created to send and receive packets on behalf of the TUN interface. Specially, for the uplink traffic(from MN to HA), all the data packets will be distributed to 3G socket or WLAN socket according to their destination IP address. In our design, a pre-configured IP address table is maintained to specify the packets that will be sent out via 3G interface. All other unmatched packets are sent on WLAN interface. If only one interface is available, all packets are transmitted via the same socket associated with this interface. There is no special processing for downlink traffic (from HA to MN) on MN side, the traffic is controller by HA. The same pre-configured IP table will be synchronized to HA, they are used to distinguish the packets sending from HA to MH. However, the source IP address will be used in HA instead.

Let's assume there are two applications (A & B) on MN and their corresponding remote node's IP addresses are 1.1.1.1 and 2.2.2.2, respectively. For the purpose of load balancing, the former traffic (A) is expected to transmit via 3G interface while the other one (B) goes

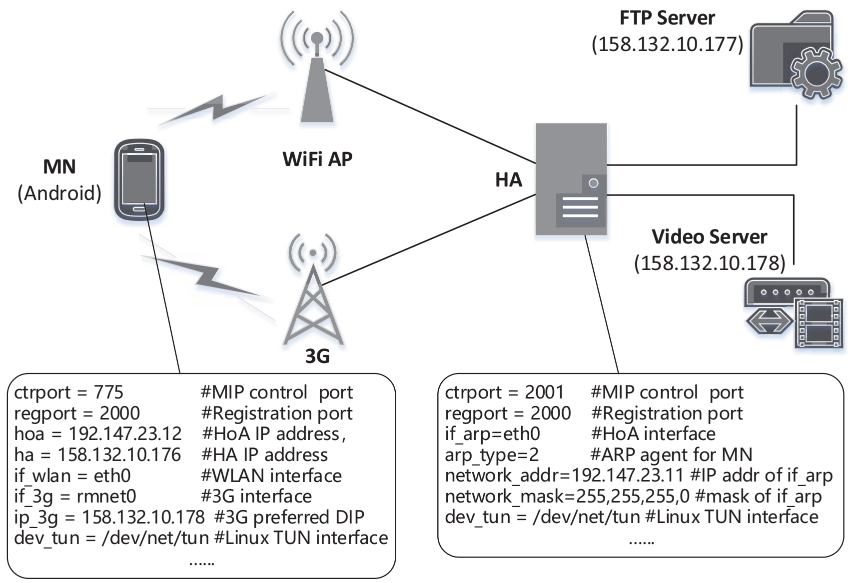

Figure 4. Evaluation of UM^{3}N Framework

to WLAN interface. When MN sends the packets to their corresponding remote nodes, all the IP packets with DIP 1.1.1.1 (A) will match a 3G pre-configured IP table and sent out via 3G interface. Once the HA receive the packets from remote hosts, the packets of the application A share a same source IP, which is application A's original DIP (1.1.1.1), thus it can be used in HA to dispatch all A's packets to the 3G socket correctly. Similar to this, all B's packets cannot match the 3G pre-configured IP table and they will be directed to the default WLAN interface.

IV. Evaluation

The components of our UM^{3}N experiments mainly includes: i) An Android phone as MN; ii) A normal server as HA and iii) two application servers as remote hosts (see Fig. 4). There is no limitation of the selected Android Phone as long as the bootloader can be unlocked and third-party ROMs are supported. This requirement is mandatory because we need to edit the *wpa_supplicant* related files to decline 3G teardown request even when WiFi ia available. In our experiment, the community open source cyanogen mod is used [10].

The HA, just like a router, performs the packets forwarding functionality between MN and remote hosts. It has two IP addresses: an uplink IP address (158.132.10.176) to connect with two remote hosts and a downlink IP address (192.147.23.11) to establish the tunnel with MN. Here these two IP addresses must be reachable via both WiFi and 3G network because the MN relies on this former to complete the MIP registration and the latter to create TUN interface. The FTP server was built directly on an Ubuntu FTP service and the video server was deployed via VLS (VideoLAN Server) [11], both of them are required to be reachable by the home agent.

In this experiment, the WiFi network supports all the major authentication methods except web authentication while the 3G network requires the corresponding cellular provider permitting UDP traffic because this is a UDP mobile IP based framework.

As stated in the configuration files in Fig. 4, all the video streaming traffic will be prioritized to transfer via 3G interface. During the evaluation, a mobile user uses VLC Direct Pro to watch video and AndFTP to download files (both Android applications can be downloaded from Goolge play market directly). There are two methods to confirm the multihoming work as expected. The first method is to install a packet capture tool on WiFi AP to monitor the destination/source IP address; The second one is to shutdown the WiFi AP to observe whether the video streaming are still working without any interruption.

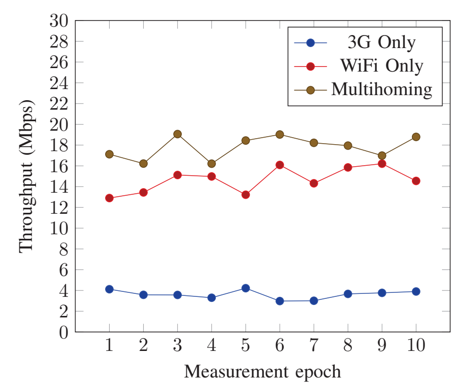

Figure 5. Throughput comparison of 3G only, WiFi only and Multihoming

A major benefit of multihoming is the improvement of throughput, which has been demonstrated in Fig. 5. Please notice that the measurements were not conducted in the same time, these data are collected in three separate experiments. However, they still reveals the throughput improvement when multihoming is applied. From our observation, the average throughputs for 3G only, WiFi only and multihoming are 3.61Mbps, 14.67Mbps, 17.82Mbps, respectively. The total throughput of multihoming increases around 21% compared to WiFi only scenario.

V. Extended Application on Handover

The previous section demonstrated the application of UM^{3}N Framework on multihoming, actually this framework can also be easily extended to handover. The major difference is that only one physical interface will be maintained. On MN, all applications interact with the virtual TUN interface but their traffic will be directed to either 3G or WLAN interface. The internal design of MN is illustrated in Fig. 6 in which the component "WiFi Monitoring" is responsible for reporting the strength of WiFi signal to the component "Handover Management" and the latter will determine whether to stop/establish the WiFi connection and establish/stop 3G connection. The "Handover Management" component also needs to notify the "Handover Execution" component to create/destroy the corresponding socket.

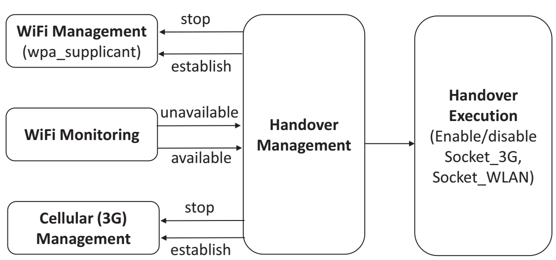

Figure 6. Application of UM^{3}N Framework on Handover

In this scenario, the applications have no idea whether the underlying transmission channels have been changed because they only interact with the virtual TUN interface. From the view of applications, the connections between MN and HA are always well maintained. Thus the seamless handover during the mobile motion can be implemented based on the same UM^{3}N Framework.

The same video streaming application in the multihoming scenario is also used to verify the performance of the handover solution. In our test, no obvious frame drops were observed in 30 fps at 720p. It is a big improvement compared to the Android intrinsic handover mechanism by which a video application has to be paused and resumed due to the change of IP address.

VI. Conclusion

This paper proposes a generic multihoming framework based on an UDP oriented MIP protocol. By the verification on an Android phone, the feasibility and availability in realistic environment have been proved. Actually this framework can also be easily applied in the seamless mobile handover scenario. Compared to the existing implementations, this framework is a light-weight and more practical solution. The future works include a unified multihoming/handover framework based on the latest Mobile IPv6 (MIPv6) protocol and the better integration with the stock ROMs (the ROMs provided by mobile device manufacturers).

Acknowledgment

The authors would like to thank Prof. Jiannong Cao, part of the work in the paper was conducted in HongKong Polytechnic University under Prof. Cao's supervisory. This work is also supported by Nanjing University of Posts and Telecommunications under project No. NY215168 and No. NY218024.

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