Analysis of the Handover Procedure in Follow-Me Cloud

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***Abstract*—*Follow-Me Cloud* (FMC) allows transparent migration of end-points (users and services) in TCP/IP networks. In this paper we describe in details the FMC handover procedures and analyze the parameters that may affect their performance. Our analysis suggests possible optimizations for such procedures.**

***Index Terms*—Software-Defined Networking, OpenFlow, Handoff performance, Follow-Me Cloud, Mobility**

I. Introduction

Follow-Me Cloud (FMC) [1] is a technology developed to overcome the current TCP/IP architecture mobility limitations and to support novel Mobile Cloud Computing applications, by providing both network end-points mobility support and the ability to reactively relocate network services depending on users' locations,

In this paper we present how FMC achieves network end-points mobility and the details of the handover procedure. We perform an analytical analysis of the FMC handover operations compared to other mobility technologies and identify key criticalities and issues.

II. Related Work

MobileIP (MIP), enables end-points mobility by introducing a network stack extension for mobility in the end-points and adding two network entities: the home agent (HA) and the foreign agent (FA). A mobile node (MN) that changes its network attachment point, in addition to its original IP address (called the *home address*), acquires a new address, the *Care-of Address* (CoA), that is used to deliver packets while the MN is visiting a foreign network. Hierarchical MIP (HMIP) further extends MIP by introducing a hierarchy in MIP. A new network entity, the *mobility anchor point* (MAP), manages MN mobility in a local domain. The final outcome of the hierarchy is a reduced signalling traffic when the MN moves inside a local domain.

Interactive Protocol for Mobile Networks (IPMN) [2] provides mobility support without assigning new addresses, by transparently changing on-the-fly a MN's address at nodes involved in the network communications, using a new TCP connection message that informs the correspondent node about address changes.

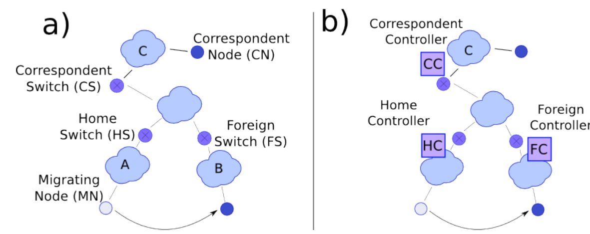

Fig. 1. a. Reference scenario; b. FMC distributed architecture

III. Follow-Me Cloud

Follow-Me Cloud (FMC) enables mobility of network end-points among different IP subnets in a TCP/IP network. FMC is applied to a TCP/IP network in which access networks are connected to a "core" network, that provides connectivity among them, through OpenFlow-enabled switches (OFS).

It realizes the split of identifier and locator concepts in the edge network, using the OFSes to enforce the splitting in a transparent manner for network end-points. Figure 1.a shows a typical application scenario, with three access networks, and explains also the names used to identify all the network devices involved. Names are assigned from the perspective of a particular migrating node (MN). Using FMC, the MN can migrate from an access network A, to an access network B. From a network perspective, MN is totally unaware that the access network on which it is residing is changed. All the ongoing communications are kept active, e.g., TCP sessions are not lost. Any correspondent node, i.e., any node that is on an access network different from A or B and that is communicating with MN, is unaware of the MN location change as well. To provide this result, FMC requires that a new IP address, belonging to the B network, is assigned to MN to work as "locator". The original IP address of MN is still used by MN itself and by any node that is communicating with MN, since it works as "identifier". For any migrated node, the FMC stores the identifier/locator mapping information, that is used to configure involved OFSes. The outcome of FMC operations is that each packet destined to a migrated end-point, before traversing the core of the network, is processed to substitute the identifier address with the locator address. Then, the locator address is substituted again with the identifier address, before the packet is delivered to MN.

FMC services are implemented through a distributed architecture of network entities called Controllers. To manage ID/LOC mapping information and to distribute it among networks, FMC uses the architecture depicted in Figure 1.b. With respect to the migrating node, the FMC architecture comprises three different roles: *Home Controller (HC)* that controls the network to which the *identifier* address belongs to; *Foreign Controller (FC)* that controls the network to which the *locator* address belongs to; *Correspondent Controller (CC)* that controls one or more CSes. The architecture is flexible enough to enable a single controller to play one, two or all the roles for the same MN, e.g., because the same controller is in charge of managing multiple networks. When a MN changes its network attachment point, an external entity detect the movement[1] and triggers the HC to start an handover procedure. HC is provided with information about current MN's IP address, i.e., the ID, and on which network MN is moving to (we call such a network nFN). HC sends a message to the FC in charge of managing nFN (the nFC), in order to obtain a LOC address to create a new ID/LOC mapping. nFC sends the generated LOC address back to HC, so that both controllers can configure the OFSes located at respective networks. If the MN was already migrated to a FN (the oFN), the controller in charge of managing such network (the oFC) is informed by HC of the new migration. oFC answers HC sending a list of the CCs that requires updated ID/LOC mapping information as well. In the last step, HC informs CCs, that in turn set up OFSes located at their networks.

IV. Handover analysis

To analyze handover performance and compare it with other mobility technologies, we consider the case of a Mobile Node (MN) moving from a Foreign Network (called oFN) to a new FN (called nFN). Our evaluation assumes that the time to exchange messages among different entities is the characterizing factor for handover performance. Since the mobility technologies presented in section II behaves differently in local and global mobility cases, we perform our analytical evaluation separating the global case from the local one. Fig. 2 presents a simplified view of the network that includes the entities adopted by considered technologies to provide mobility, and introduces variables names used to identify the network delays among the different entities. Network delays experienced by messages exchanged in the network, for the considered technologies, can be obtained summing the presented variables, as explained in table I. Our evaluation has been performed considering 5 different scenarios. In each scenario a single variable changes its value in a given range, as shown in table II, while the other variables remains fixed to the default values presented in table I.

We compared FMC to MIP, HMIP and IPMN. We computed handover times summing the delays of the messages sequence required by each technology to perform the process (See table III). The results of our performance comparison are presented

[1]The definition of such a service is out of the scope of this paper. It could be, e.g., a network stack's layer 2 service

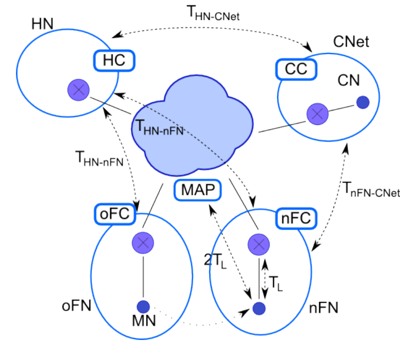

Fig. 2. Graphical representation of delay variables presented in Table I

TABLE I
DELAY VARIABLES

Variable	Description	Expression	Default Val. (ms)
T_L	*Local delay*		1
T_{HN-oFN}	$HN <-> oFN$		10
T_{HN-nFN}	$HN <-> nFN$		15
$T_{HN-CNet}$	$HN <-> CNet$		20
$T_{nFN-CNet}$	$nFN <-> CNet$		20
T_{HC-oFC}	$HC <-> oFC$	T_{HN-oFN}	10
T_{HC-nFC}	$HC <-> nFC$	T_{HN-nFN}	15
T_{HC-CC}	$HC <-> CC$	$T_{HN-CNet}$	20
T_{MN-HA}	$MN <-> HA$	$T_L + T_{HN-nFN}$	16
T_{MN-CN}	$MN <-> CN$	$2T_L + T_{nFN-CNet}$	22
T_{MN-MAP}	$MN <-> MAP$	$2T_L$	2

TABLE II
ANALYSIS SCENARIOS

	Local	HN-oFN	HN-nFN	HN-CNet	nFN-CNet
Range	1-10	10-55	15-60	20-65	20-65
Scenario #	0	1	2	3	4

in figure 3. FMC is less influenced by local delays (T_L), since only controllers, that are placed at the edge of access networks, are involved into the handover, but it shows poor performance when the delay between HN and oFN, or the delay between HN and CNet increases. In scenario 2 it behaves like MIP and HMIP (actually it is slightly faster), while it is unaffected by the increasing of nFN-CNet delay.

For the local mobility case, we compared FMC only against HMIP, since other technologies does not provide any enhancement for this specific case. FMC architecture is flexible enough to allow a Controller to play more roles, hence, we assume that, in a local mobility case, the same Controller could be in charge of managing more than one network. In FMC we will call "local domain" the set of networks controlled by the same Controller. We considered the configurations presented in table IV. HMIP usually performs better, since it requires message exchanges only among MAP and MN (See figure 4). The sole case in which FMC can compete with HMIP is when all the involved networks are under the management of a single Controller, i.e., when all the involved end-points are in same local domain.

V. Discussion and Conclusions

FMC provides several features that other technologies provide in a separately, e.g., end-point transparency, ID/LOC splitting, local mobility optimizations, avoiding, at the same time, the use of tunneling to reduce the overhead caused

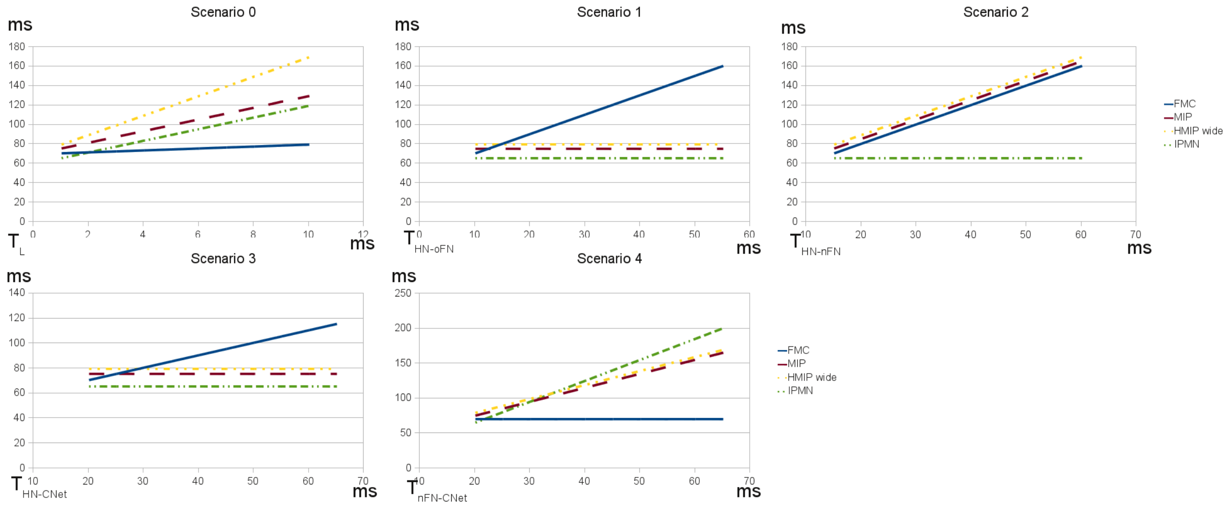

Fig. 3. Handover delays evaluation for global mobility

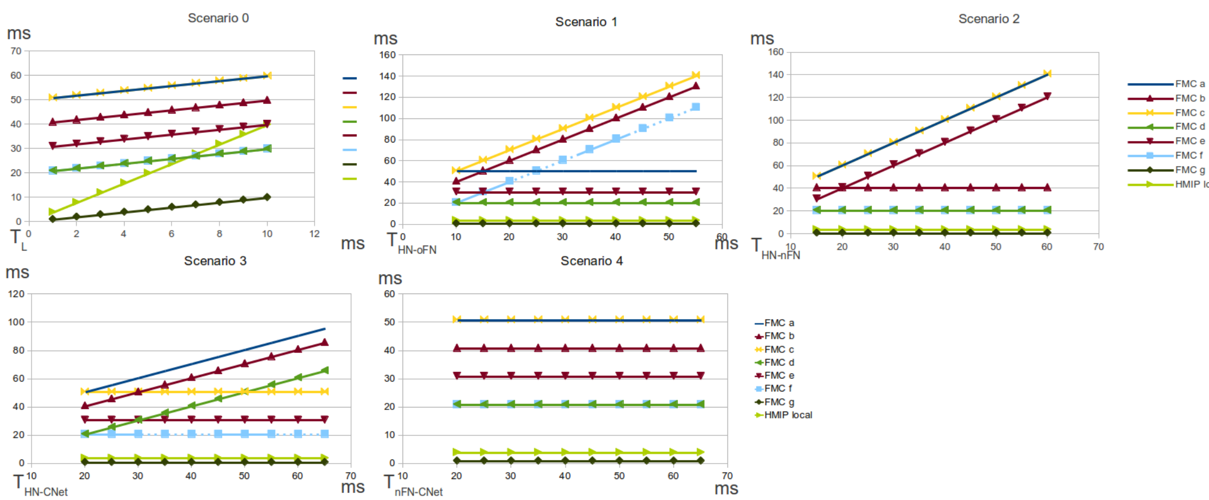

Fig. 4. Handover delays evaluation for local mobility

TABLE III
HANDOVER DELAYS

Solution	Formula
FMC	$2T_{HC-nFC} + 2T_{HC-oFC} + T_{HC-CC} + T_L$
MIP	$2T_{MN-HA} + 2T_{MN-CN}$
HMIP (local)	$2T_{MN-MAP}$
HMIP (global)	$2T_{MN-MAP} + 2T_{MN-HA} + 2T_{MN-CN}$
IPMN	$3T_{MN-CN}$

TABLE IV
FMC CONFIGURATIONS

#	Controller Joint Networks	Formula
a	HN, oFN	$2T_{HC-nFC} + T_{HC-CC} + T_L$
b	HN, nFN	$2T_{HC-oFC} + T_{HC-CC} + T_L$
c	HN, CNet	$2T_{HC-nFC} + 2T_{HC-oFC} + T_L$
d	HN, oFN, nFN	$T_{HC-CC} + T_L$
e	HN, oFN, CNet	$2T_{HC-nFC} + T_L$
f	HN, nFN, CNet	$2T_{HC-oFC} + T_L$
g	All	T_L

by encapsulation. Moreover, the FMC handover process still shows performance that in many cases are comparable or better than the one experienced by other technologies. Nevertheless, there are rooms for optimizations and enhancements, both in the global and local mobility cases, that should be taken into account in FMC future developments.

Acknowledgements

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References

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