Enhanced Handover Signaling through Integrated MME-SDN Controller Solution

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***Abstract*—The future wireless networks are expected to be extremely dense and heterogeneous, with the users experiencing multi-connectivity through the multiple available radio access technologies (RATs). These prevalent characteristics, along with the strict QoS requirements, renders the handover (HO) process optimization as a critical objective for future networks. Along side the evolving network characteristics and methodologies, an evolving network architecture needs to be considered as well. Such evolution should not only facilitate HO process enhancement, i.e., reduction in HO delay and signaling, but it should also allow for a smooth transition from current to future wireless networks. Hence, in this work we firstly present an evolutionary core network entity called the Integrated MME-SDN Controller and the associated network architecture. The proposed architecture provides a migratory path for the existing 3GPP cellular architectures towards the 5G networks. Next, we discuss the benefits and challenges of such an architectural approach, with one of the benefits being a manageable CAPEX for the network operators through its transitional nature. Subsequently, utilizing the aforementioned proposed architecture, we present the handover process enhancement for the current 3GPP defined HO processes. We quantify the improvements achieved in terms of latency, transmission and processing cost for the different 3GPP HO processes. We also show that the proposed HO mechanism leads to a significant reduction in latency and signaling for certain types of HOs which, as a consequence, will critically benefit any dense and heterogeneous wireless system, such as 5G.**

***Index Terms*—LTE, MME, SDN, Handover, Mobility Management, Latency, 5G.**

I. INTRODUCTION

The future wireless networks are expected to be extremely dense and heterogeneous, wherein the users can experience multi-connectivity. Whilst this envisioned densification and heterogeneity will lend significant benefits to the users (e.g., in terms of improved Quality of Service (QoS)) and the network (in terms of better area spectral efficiency, etc.) [1], [2], the efficiency of the handover (HO) process will become extremely critical. The reason being, increased heterogeneity will result in a rise in the inter-RAT handovers for the users. Further, the aforesaid densification will also lead to frequent handovers (FHOs). Hence, the current 3GPP handover strategy [3] will be rendered inefficient, thus necessitating further scrutiny in terms of its latency and required signaling.

Additionally, the migration strategies of current network architecture to the 5G network architecture will be equally critical, as it will directly impact the Capital Expenditure (CAPEX) and Operating Expenditure (OPEX). Also, the time to migrate to a fully Software Defined Networking (SDN) enabled and softwarized 5G network architecture, such as those proposed in [4]–[9], will be another critical factor. Note that, current proposals for SDN based LTE Evolved Packet Core (EPC) [4]–[6] as well as the recently proposed 5G architecture by 3GPP [9] highlight the emphasis on SDN and Network Function Virtualization (NFV) for 5G. Moreover, there has already been a considerable effort by the industry towards SDN-enabled EPC solutions [10]. Consequently, it will be important to take these architectural proposals into account whilst developing any future architectural and mobility management (MM) solution.

Next, research efforts such as [11] evince a new SDN based paradigm for MM known as Mobility Management as a Service (MMaaS), wherein SDN based core network (CN) can utilize the available network and user context and implement on-demand MM solutions. Such an on-demand MM solution, which utilizes information such as mobility profile, flow type, etc., will enhance the scalability and flexibility of the network in handling the complex 5G MM scenarios. Further, in [9], discussions on the MM aspect have been provided by the 3GPP SA2 group. Whilst, the discussion is extensive on the MM states as well as the session and service continuity aspects along side their comparison/evolution from the current 3GPP standards, the handover signaling required for Inter- and Intra-RAT HO and its evolution from the current standards is lacking.

Given the above discussion, we can state that the existing proposals, including the 3GPP 5G architecture, at this stage do not specify the signaling approach that will be utilized to perform handovers in the highly complex wireless environments that will prevail in 5G networks. Further, the aforementioned proposals also fail to provide a definite path to evolve from current to the 5G network architecture proposed by 3GPP [9]. The operators, as a consequence, will be faced with the difficult challenge of either determining a suitable migratory strategy or incurring a high CAPEX to adopt the newly proposed 5G architecture.

As a solution to these challenges, firstly, building on the SDN-EPC convergence trend as well as the 3GPP 5G architecture, we propose a new core network entity named as the

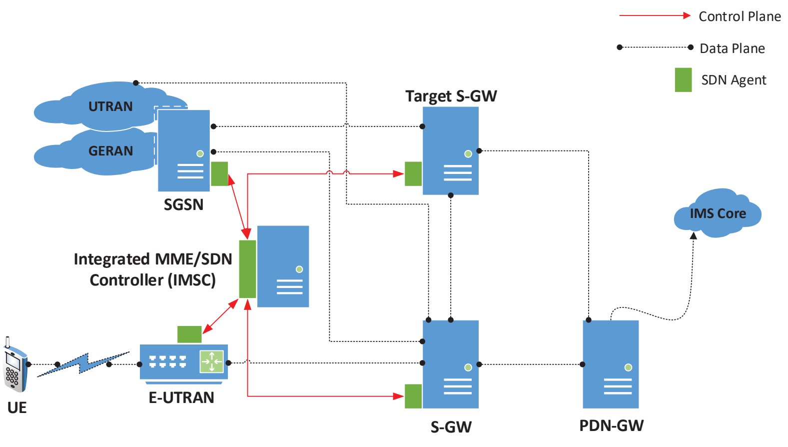

Fig. 1. Proposed Network scenario with IMSC framework.

Integrated MME-SDN Controller (IMSC) and the corresponding network architecture. Such a solution aims at providing a transitional approach from current to future networks, hence reducing the time to market and CAPEX as compared to directly adopting fully softwarized SDN based networks. Next, we study the current 3GPP standards for HO signaling procedures and suggest improvements that can be achieved with the proposed architectural vision. The performance improvements achieved with the proposed solution are evaluated for different HO types defined by 3GPP, including Inter- and Intra-RAT HOs. The results show that latency reductions of up to 48.83%, transmission cost reductions of up to 40%, and processing cost reductions of up to 28.57% are achievable with the proposed mechanism. Although certain studies from the literature target HO enhancement for future networks such as [6], our work is the first study to propose an evolutionary network architecture along with an improved HO process for the various HO types defined by 3GPP.

Thus, in this paper the new core network entity, i.e. the IMSC, and the corresponding network architecture are presented in Section II. We also discuss the benefits and the implementational challenges that will be associated with the IMSC based solution. The signaling sequence exploiting such architecture for the 3GPP-defined HO procedures, have been then discussed in Section III. Next, in Section IV we develop the analytical framework for the comparative analysis between the proposed and current methods. Subsequently, in Section V the results and the comparative analysis have been provided. This paper is then concluded with Section VI.

II. THE INTEGRATED MME-SDN CONTROLLER (IMSC) SOLUTION

The IMSC combines the capabilities of the MME from the existing LTE-EPC and the SDN Controller (SDN-C). The IMSC, like the MME and SDN-C, will be a centrally located entity with full view of its network domain. Additionally, the IMSC will be employed such that the data plane (DP) and control plane (CP) connections between other 3GPP network entities are unaltered. Such an approach simplifies the migration of the current networks to the future networks, hence, also reducing the CAPEX for the operators. Further, the IMSC consists of an SDN agent that communicates with the other network entities, which are also modified by the addition of an SDN agent, to execute the improved handover strategies.

We present the envisioned network architecture in Fig.1. Note that, while the IMSC is connected to all the network entities via the SDN agents, it is not connected directly to the Radio Network Controller (RNC). Since, in the UMTS network, the Serving GPRS Support Node (SGSN) is responsible for coordinating the session and control plane signaling with the RNC, our network architecture avoids modifying that framework. Henceforth, the IMSC is connected to the SGSN, which then manages the communication with the RNC and the NodeB/Base Transceiver Stations (BTSs).

Further, when compared holistically with the current network architecture, the transition of the CN entities from specific (and modular) CP/DP boxes to generic hardware boxes controlled and managed by a centrally located SDN controller, as envisioned in the 5G network architecture [9], has been established. The evolutionary trend is further reinforced from the fact that, the centrally located IMSC in the proposed architecture, an evolution of the MME in the current EPC, improves the CP signaling within the CN through its SDN capabilities. Specifically in Section III, we will explore how, through efficient remapping of current handover signaling messages to a new set of signaling messages, the CP signaling involved during the handover preparation phase is improved while ensuring minimal architectural disturbance.

A. Benefits of Integrated MME-SDN Controller

The IMSC, through its centralized location and the SDN-C capabilities, holds significant benefits for the current networks to execute MM related tasks. These benefits have been discussed as follows:

- *Global view*: The global (or locally global) view [11] of the network allows the IMSC to acquire the required parameters from the core as well as the access network. By gaining access to these parameters, the IMSC can then formulate improved solutions through algorithms or frameworks defined within the MM Virtualized Network Functions (VNFs) at the Northbound Interface (NBI) of the IMSC.
- *SDN capabilities*: SDN is a concept that allows for the decoupling of the CP from the DP [1]. Thus, the IMSC, through its SDN agent can push rules and critical CP information to each of the network entities it is connected to. As will be seen in Section V, this results in significant performance improvement for the HO signaling.
- *Evolutionary Concept*: The current IMSC configuration presents a core network entity that has the combined capabilities of both the MME and SDN-C. This shows an entity that sets up an evolutionary trend, rather than presenting a sudden jump to a new network architecture followed in many of the current research efforts [8], [12]. The benefit of such an evolutionary CN entity is that it helps to provide the continuity of legacy concepts, whilst introducing the next generation network concepts. Further, this also helps to reduce the CAPEX.
- *Handover Enhancement*: As will be discussed in more detail in Section III, the handover preparation signaling forms a significant portion of the overall HO execution time. And hence, taking advantage of its global view and SDN capabilities, the IMSC allows remapping of the existing handover preparation signaling messages to a new and reduced set. This consequently reduces the overall HO latency as well as the transmission and signaling cost.

B. Design and Implementation Challenges

Given the proposed architectural changes, as shown in Fig.1, we perceive that there will be certain challenges that will be encountered in the design and implementation process of the IMSC. One of the main challenges will be to modify other CN entities to include an SDN agent. The reason being, there will be a certain CAPEX involved with such a wide scale network upgrade. However, it is our belief that the incurred CAPEX will be much less than the complete overhaul proposed in some of the current research efforts [6], [7] as they imply the introduction of new CN entities, which will consequently result in a very high CAPEX for the operators. Additionally, the proposed evolution is currently in the migration path of many operators as evidenced by the SDN-enabled LTE solutions.

Next, since we introduce an SDN based system, the issue of scalability of the proposed solution will also be one of the design challenges. However, a short preliminary analysis reveals that, because the IMSC will communicate only with the CN entities without any handshake procedures (Sections III-V), the proposed solution will be highly scalable. Concretely, by avoiding handshakes the IMSC helps to reduce the number of CN signaling messages. And given the ultra-dense nature of 5G networks, a reduction in the CN signaling will enable the network to manage more users successfully. Hence, the IMSC facilitated reduction in CN signaling will enhance the scalability of the proposed solution.

Lastly, for the modification of the HO preparation signaling process, a remapping of the original messages to a new message set would be required. To be able to gather the Information Elements (IEs) and pack them in the proposed messages will hence be equally challenging. Further, to maintain the same set of IEs being used, i.e., the IEs used in the legacy and proposed mechanism are not changed in their structure and functionality, in the complete signaling process will be equally critical to enable the evolutionary trend. In this paper, we take up this challenge and consequently, the design and analysis process has been detailed in the subsequent sections.

III. MODIFIED HANDOVER PREPARATION PHASE SIGNALING

Of the three main steps involved in the handover process, i.e., *Handover preparation*, *Handover execution* and *Handover completions* [3], the handover preparation phase will be extremely critical given the dense and heterogeneous scenarios that will prevail in 5G networks. Concretely, the handover preparation phase consists of CP signaling to establish GPRS Tunneling Protocol (GTP) tunnels between the CN entities, creation and exchange of Tunnel Endpoint Identifiers (TEIDs), and radio resource allocation. These aforementioned steps are vital to perform a successful handover, and hence, need to be executed in a time frame that will lead to a tolerable overall handover latency. Further, in the 5G networks, to avoid loss of connectivity and degraded QoS owing to FHOs, the current handover preparation phase will need to be improved. From the existing LTE to UMTS/2G Inter-RAT HO process depicted in Fig. 2, it can be observed that this process may involve handshakes (i.e., messages 4, 4a, 6, 6a, 8 and 8a), thus leading to an increased overall HO latency.

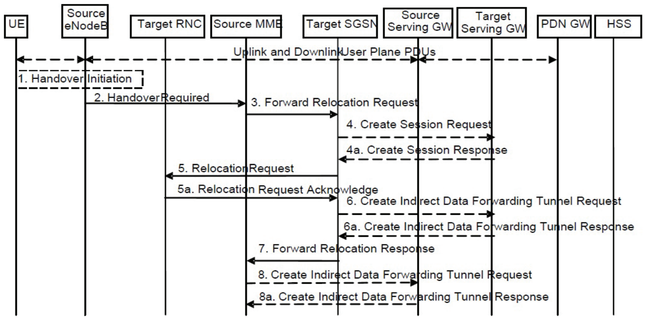

Fig. 2. Legacy Inter-RAT HO signaling (LTE to UMTS/2G network [3]).

And hence, in this section, we propose a more compact HO preparation phase signaling. The proposed mechanism is illustrated through Figs. 3 and 4. Note that, due to space constraints and to understand the maximum extent of benefits from the proposed solution, in the text we only discuss the Inter-RAT HO from LTE to a UMTS/2G network that involves indirect tunneling and Serving Gateway (S-GW) relocation[1]. Here, S-GW relocation implies that during the handover the user not only changes its access point but also the S-GW to which it is attached. Further, indirect tunneling refers to the scenario where the Source/Target Serving Gateway (S/T-SGW) does not directly transmit the incoming downlink (DL) packets to the RNC. Instead, it routes the packets to the SGSN, which then forwards it to the RNC. It is important to note that, while direct and indirect tunneling are DP procedures, the IEs required to setup these aforesaid tunnels are different. For more details regarding the IEs and the message composition we refer the reader to [3].

Fig. 3 shows that the number of messages required to perform handover preparation is reduced to 10 from the 14 involved in the legacy mechanism. Note that the two messages from the HO execution phase in the legacy signaling mechanism, i.e., *Handover command* and *HO from E-UTRAN Command*, have also been considered as part of the HO preparation phase. The reason being, until the handover parameters are acquired by the user equipment (UE), which is sent specifically in the aforesaid commands from the CN, the handover from the user point of view is still in the preparatory phase.

We also observe that the *Handover Initiation*, *Handover Required*, *Handover Command* and *HO from E-UTRAN Command* are mapped as is from the legacy messages, i.e., the IEs for the aforesaid messages are exactly as they are in the legacy procedure. Additionally, the *Relocation Request* and *Relocation Request Acknowledge* messages, i.e., legacy messages 5 and 5a, remain unaltered as they are already optimized for the IMSC architecture.

The messages that have been altered are discussed in detail as follows:

- *Resource Allocation Request + Tunnel Setup (P3a)*: This message is a direct descendant of the *Forward Relocation Request (legacy message 3)* from the legacy signaling mechanism [3]. Hence, all the IEs from the legacy message are mapped to message P3a of the proposed approach. Since the IMSC is connected to all the other CN entities, through message P3a it can thus allocate the SGSN its TEID and address for the CP (legacy message 4), the T-SGW addresses and TEIDs (legacy message 4a), and the SGSN TEID and address for DL data forwarding (legacy message 6).
- *Source S-GW Tunnel Setup (P3b)*: The Source S-GW, in the event of an S-GW relocation, will need to tunnel the DL packets to the T-SGW. This will require the S-SGW to know the TEID and address of the T-SGW as well as it will have to allocate TEIDs and addresses for receiving DL packets from the eNB. This information is obtained through the handshake involving legacy messages 8 and 8a. Given the IMSC's global knowledge and capabilities in allocating and informing CN entities of their TEIDs and transport layer addresses, the IEs of these two messages are henceforth mapped to message P3b of the proposed signaling mechanism.

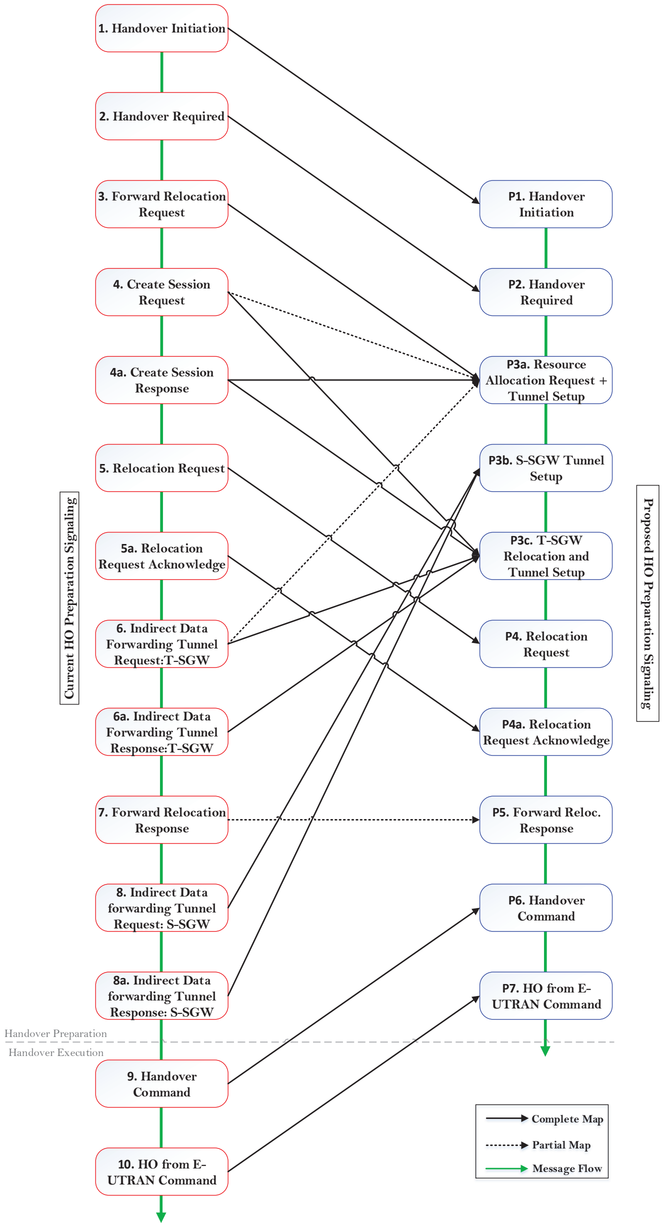

Fig. 3. Proposed handover signaling map for Inter-RAT HO from LTE to UMTS/2G when S-GW is relocated and indirect tunneling exists.

- *Target S-GW Relocation and Tunnel Setup (P3c)*: Message P3c is composed of the IEs from legacy messages 4, 4a, 6 and 6a of the legacy signaling mechanism. Since the IMSC has the global knowledge of the allocated addresses and TEIDs for each of the CN entities, it is

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[1] Message maps and signaling sequence for other scenarios are provided in https://wireless.upc.edu/en/research/hosignaling.pdf/view. Analysis for all the scenarios is provided in Section V.

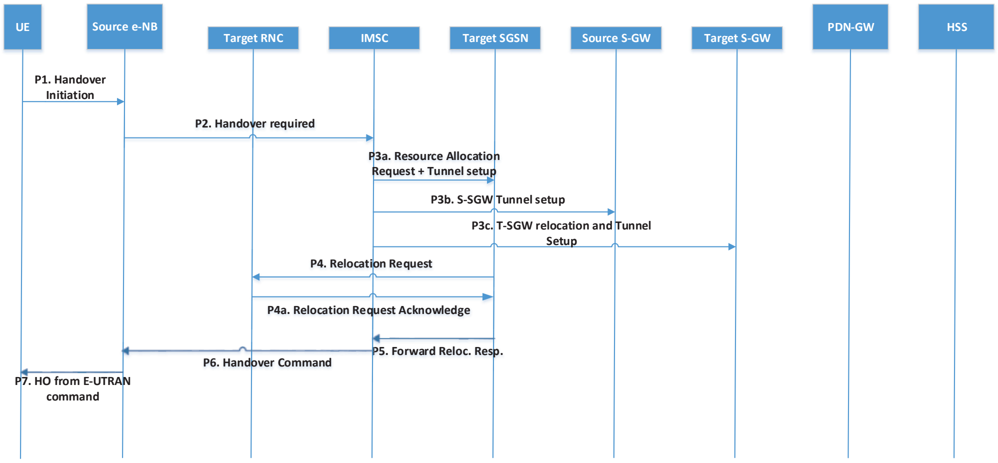

Fig. 4. Proposed handover signaling sequence for Inter-RAT HO from LTE to UMTS/2G networks when S-GW is relocated and indirect tunneling exists.

possible for it to inform the T-SGW about the TEIDs and addresses of the SGSN without the entities having to perform a handshake.

- *Forward Relocation Response (P5)*: This message is a direct descendant of the *Forward Relocation Response* (legacy message 7) from the legacy signaling mechanism. The CN entities involved in this message are the Target SGSN and the IMSC. Whilst, most of the IEs are carried over to message P5 in the proposed signaling mechanism, IEs such as the SGSN TEID and addresses need not be transferred to the IMSC. This is so because the IMSC itself is responsible for the allocation of the TEIDs and addresses, and hence, it has the corresponding knowledge.

And so, with the new message mapping, we now discuss the signaling mechanism described in Fig. 4. It can be observed that the *Handover Initiation, Handover Required, Handover Command* and *HO from E-UTRAN command* sequence and operation remain unaltered, as mentioned earlier. However, messages P3a, P3b and P3c, since they are executed by the IMSC, can be implemented in parallel. This, as will be seen in Section IV, results in latency gains. Further, the *Relocation Request* and *Relocation Request Acknowledge* remain unaltered in their operation. However, in the proposed mechanism they are numbers P4 and P4a respectively, whilst in the legacy scheme they are numbers 5 and 5a. Next, the modified *Forward Relocation Response* message is sent to the IMSC, which combines this with the TEID and addresses of the S-SGW and SGSN that it has already, and forwards it to the eNB as the *Handover Command*. Lastly, the eNB sends the *HO from E-UTRAN command* to the UE to end the HO preparation phase.

IV. ANALYTICAL FRAMEWORK FOR HO PERFORMANCE EVALUATION

To conduct the quantitative analysis of the proposed signaling strategies, a mathematical formulation of the analysis parameters, i.e., latency, transmission and processing costs, has been provided in this section. For the latency analysis, we consider the parallel link delays and the processing (Proc.) delays. Concretely, it is defined as

$$\text{Latency} = \sum \text{Parallel Link Delays} + \sum \text{Proc. Delays}. \quad (1)$$

where the parallel link delay defines the maximum link delay amongst the parallelized messages as the latency associated with that step. This can be expressed as

$$\begin{aligned}\text{Parallel link delay} \quad &= \quad \max(\textit{Link delay msg 1}, \ldots, \\ &\quad\quad \textit{Link delay msg N}), \end{aligned} \quad (2)$$

where *Link delay msg 1*, $\ldots$, *Link delay msg N* are delays for the N messages that are being executed in parallel. Additionally, and since all the packets can be transmitted and processed in parallel, we only consider a single processing delay instance for the N messages executed in parallel.

Next, for the transmission cost, we consider all the link delays. It is defined as

$$\text{Transmission Cost} = \frac{\sum \text{Link Delays}}{1\text{ms}}. \quad (3)$$

In layman terms, this metric corresponds to the total amount of time the links (i.e., network resources) are kept busy for HO signaling.

For the processing cost, we adopt the analytical methodology followed in [13] and define it as the number of messages generated in HO preparation phase. Then, to calculate the percentage saving in processing cost from the proposed setup, we use the following formula:

$$\text{Proc. Cost Saving} = \frac{MSG_{Legacy} - MSG_{Proposed}}{MSG_{Legacy}} * 100\%, \quad (4)$$

where, MSG_{Legacy} is the number of messages in the legacy approach for HO preparation and $MSG_{Proposed}$ is the number of messages in the proposed approach for HO preparation.

Next, we define the values for the parameters that have been utilized for this analysis. Since the analysis is being performed on a cellular network setup, the parameters governing the deployment vary depending on operator requirements. Hence, we utilize the link delays, derived from a Japanese cellular operator setup [14] and Cisco [15], presented in Table I.

TABLE I
LINK TYPE AND CORRESPONDING DELAYS IN PROPOSED ARCHITECTURE

	Link Type	**Link Delay**
1.	UE-eNB	1ms
2.	eNB-IMSC	7.5ms
3.	IMSC-SGW	7.5ms
4.	eNB-SGW	6ms
5.	IMSC-SGSN	1ms
6.	SGSN-RNC	6ms
7.	SGSN-SGW	7.5ms
8.	IMSC-IMSC	15ms

It is important to state that, as in [16], we consider the MME (IMSC in the proposed framework) and SGSN to be co-located. Additionally, we assume a 15ms IMSC-IMSC delay, based on the premise that IMSCs are located at the national/regional level of any network deployment. Consequently, the link delay between any two IMSCs is expected to be greater than the maximum link delay within a single IMSC domain. Hence, for analysis purposes, an assumption of two times the greatest link delay within an IMSC domain has been considered for the IMSC-IMSC link. Lastly, for the latency computation, we consider the processing delay to be 4ms in all CN entities, as in [15].

V. RESULTS AND COMPARATIVE ANALYSIS

We first present the results for the latency analysis in Table II, both for the legacy as well as for the proposed mechanism, and for the different types of handover (i.e., Inter- and Intra-RAT HO with/without S-GW relocation and involving direct/indirect tunneling). Note that, Intra-MME/S-GW S1 Intra-RAT HO and X2 Intra-RAT HO have not been considered for the analysis given their already optimized nature. The application of IMSC solution will neither provide any benefits nor any penalties to these Intra-RAT HO scenarios.

From Table II, it is evident that for scenarios where legacy mechanism takes in excess of 100ms to complete the HO preparation, the proposed approach provides maximum benefits (except the Intra-RAT HO scenario where there is no S-GW relocation) owing to the presence of more optimizable message entities, i.e., the message exchanges can be improved much more as compared to the other scenarios. Further, it is important to state here that parallelizing the transmission of multiple messages helps in reducing the latency significantly. Additionally, from Table II, it can be deduced that the proposed mechanism provides at least a 20.12% reduction in latency across all the different types of HO scenarios explored in this work.

TABLE II
HANDOVER LATENCY IMPROVEMENT ANALYSIS

Handover Type	**Legacy Mechanism**	**Proposed Mechanism**	**Percentage Latency Reduction**
1.X.a†	128 ms	65.5 ms	48.83%
1.X.b†			
1.Y.a†	82 ms	65.5 ms	20.12%
1.Y.b†		58 ms	29.27%
1.X.a*	129.5 ms	65.5 ms	49.42%
1.Y.a*	82 ms	65.5 ms	20.12%
2.y	113 ms	90 ms	20.35%
2.x	159 ms	90 ms	43.40%

1: Inter-RAT HO; **2:** Intra-RAT HO; **a:** Indirect Tunnel; **b:** Direct Tunnel
†LTE to UMTS/2G; **X:** with T-SGW; **x:** inter-MME and S-GW
*UMTS/2G to LTE; **Y:** without T-SGW; **y:** inter-MME and intra-SGW

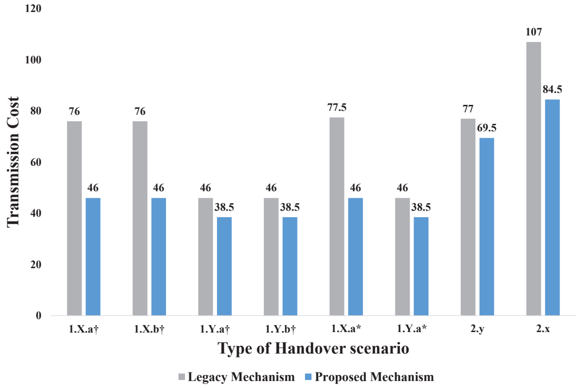

Fig. 5. Transmission cost analysis for multiple HO scenarios (X axis notations have been re-utilized from Table II).

Next, we present transmission cost benefits that the proposed mechanism provides through Fig. 5. As seen in the figure, the proposed Inter-RAT HO mechanism provides around 40% reduction in transmission cost when relocation of S-GW is involved. For the Inter-RAT HO scenario where there is no relocation of S-GW, the reduction in transmission cost is 16.30%. Similarly, in the Intra-RAT HO scenario when there is no S-GW relocation the transmission cost saving is 9.74%, while the cost saving during S-GW relocation is 21.03%. It can thus be concluded that the messaging sequence involving S-GW relocation scenarios can be improved much more than other scenarios.

Further, from Table III, it can be observed that similar to the transmission cost, the processing cost is reduced the most for scenarios where the S-GW relocation takes place. Quantitatively, the processing cost reduction for the Inter-RAT scenarios with S-GW relocation is 28.57%, while that for the scenarios without S-GW relocation is 10%. Additionally, the processing cost saving for the Intra-RAT HO when both the IMSC and S-GW are relocated is 21.43%, while that for the Intra-RAT HO without S-GW relocation but with IMSC relocation is 10%.

These quantitative improvements offered by the IMSC solution in HO latency, transmission cost and processing cost will

TABLE III
PROCESSING COST ANALYSIS

△Handover Type	Processing Cost		
	Legacy Mechanism	Proposed Mechanism	% Saving
1.X.a†	14 messages	10 messages	28.57 %
1.X.b†			
1.Y.a†	10 messages	9 messages	10 %
1.Y.b†			
1.X.a*	14 messages	10 messages	28.57 %
1.Y.a*	10 messages	9 messages	10 %
2.y	10 messages	9 messages	10 %
2.x	14 messages	11 messages	21.43 %

△The notations have been re-utilized from Table II

consequently translate into savings in highly valuable network resources such as network bandwidth and computational capacity, as well as leading to faster HO for users thus resulting in better QoS (less HO failures, etc.).

VI. CONCLUSION

In this work, we have proposed a new CN entity, namely the IMSC, and the IMSC based network architecture, which is an evolutionary architecture, allowing for a smooth transition from current to future (5G) networks. We then explored the 3GPP standards for Inter- and Intra-RAT HO, and proposed an enhanced signaling mechanism for the HO preparation phase, which will be an important element for efficient MM mechanisms for the highly dense and heterogeneous future networks. The improved mechanism involves the IMSC taking responsibility for setting up tunnels and reducing handshakes between other CN entities for HO preparation.

Through our analysis, we showed that the proposed signaling mechanism can provide up to 48.83% reduction in latency. Additionally, the proposed mechanism provides up to 40.46% reduction in transmission cost and up to 28.57% reduction in processing cost. It is important to state here that, while the proposed mechanism does not provide any gains for the Intra-MME/S-GW S1 Intra-RAT HO and X2 Intra-RAT HO, it does not degrade their performance either. Hence, it is shown that the proposed solution facilitates in the cost and resource effective evolution of the current MM strategies and network architecture towards 5G.

As a future work, we intend to carry out further research on the aspect of scalability of the proposed handover signaling mechanism. Since as discussed in the Section II, scalability will be a major design challenge, an analysis into the same will be relevant to providing a deeper insight into the performance of the proposed mechanism and architecture.

ACKNOWLEDGMENT

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