Context-Aware Location Management of Groups of Devices in 5G Networks

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Abstract. Location Management (LM) is an important function of mobile cellular networks that enables network to locate the users. Mechanisms applicable in legacy systems are not able to cope with the vast increase of devices and the strict communication requirements expected in 5G networks. In this paper we propose a novel scheme for LM that exploits mobility context of User Equipments (UEs), keeps track of their location with high accuracy and pages small number of cells when incoming calls arrive. The analysis shows that Location Management is significantly benefitted from the proposed mechanisms.

Keywords: Location Management · Location update · Paging · 5G cellular networks · Cluster-based communication

1 Introduction

According to forecasts [1], by the year 2019, operators worldwide will have to support more than 8 billion of smart phones. This vast increase of wirelessly connected devices increases the control information that has to be exchanged thus stretching the networks' performance to the limits. Additionally, the deployment of small cells will also create additional overhead to the network components [2]. To efficiently support such communication needs, it is required to optimize control functions for avoiding bottlenecks of control channels. One specific area that calls for improvement is Location Management (LM) [3], which comprises two processes, one related to Location/Tracking Area Update (TAU) and one to location search/paging. The former is an occasional process during which UE regardless if it is in idle or connected state, sends information related to its current location to the network – the user location is linked to Tracking Areas (TA) which are sets of cells, and Tracking Area List (TAL) is a list of TAs assigned to a is a user. When a users moves out of the boundaries of his TAL he performs a TAU and the network assigns to him a new TAL. On the other hand, paging is a process initiated from the network so as to discover the UE when it is in idle state.

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Between TAU and Paging processes there is a signaling trade-off. In particular, large TAs and/or long TALs reduce the number of updates but increase drastically the number of paged cells and vice versa. Hence, it is important to use LM schemes that keep a concise set of location information for all UEs, while optimizing the signaling overhead for finding them.

Existing solutions for TAU can be roughly classified into two main categories; user-centric approaches that monitor the activity of each user [4, 5], and solutions dictating periodic network reconfiguration based on network traffic to alleviate the overall LM signaling [6, 7]. Paging schemes aim to improve the efficiency of the 3GPP standards (i.e. blanket-paging scheme [8]) that is used in legacy systems by minimizing the paging signaling. In [9, 10] sequential paging of subsets of TAL is proposed. These are further extended with Paging Area shuffling and concurrent users' serving [11], or hierarchical paging schemes [12, 13].

One promising solution for handling the location update and paging challenges in 5G networks relates to group communication. Group based TAU will enable performing updates more often thus significantly reducing the load in the paging channels. Towards this direction, in this paper we propose a Context Aware Location Management (CALM) mechanism in which only one device performs TAU on behalf of a group which is being formed for application specific purposes (e.g., car to car communication) based on context information. The intra cluster communication (for cluster formation and maintenance) takes place using secondary interfaces such as 802.11p.

The rest of the paper is organized as follows. In Sect. 2 we introduce our novel mechanism for efficient LM of UEs in wireless networks. The method can be applied to vehicular ad-hoc networks, and machine-type communication devices, but can also be applied to human-centric devices. Then, in Sect. 3 we provide the experimental results that compare our solution against the state of the art solutions and finally, Sect. 4 concludes the paper summarizing our work.

2 CALM - Context-Aware Location Management

The proposed solution solves the mentioned problems and achieves efficient LM for UEs in wireless networks. The mechanism takes advantage of existing clustering protocols (e.g., the one in [14]), where grouping is done based on time-stamp, speed, direction, etc. UEs form groups dynamically without network intervention and Cluster Members (CMs) have the possibility to communicate directly without the intervention of the cellular network.

The main goals of the mechanism are to allow a single device, namely Cluster Head (CH), to update the location of all the CMs, thus reducing the TAU overhead for all the members of the cluster, increase the granularity of TAUs and thus increase considerably the paging accuracy. During the initialization phase the CMs of a group will turn off periodic TAU timers and stop sending TAUs when crossing the borders of a TA. From that point on CMs will communicate only with the CH via a secondary interface (e.g. 802.11p). In the proposed scheme when the CH sends group's location performs an RRC connection request but instead of requesting the establishment of a signaling connection so as to perform a higher layer TAU, sends a modified RRC connection establishment request to signify that instead of establishing a signaling connection, the BS should reject this request and notify instead the Location Server about the current location of the group. Whenever the Location Server receives the CH's location from the BS it may proactively produce a new TAL based on this information and the Group ID. Then, since the network is aware of the location and the cluster information, it may accurately determine the Paging Area and there is no need to communicate the updated TAL to the CH or any CM, leading thus to further reduction of signaling. The proposed scheme, called RRC+ since it is based on enhancements of the RRC protocol, can be used on per cell basis or on any other granularity defined by the network, after CH performs cell selection/reselection procedure. Additionally, in order to avoid missing the track of any device when a UE becomes CM it may keep the standard LM functions active until the network has received the information regarding it being member of a group. During this time the UE is still reachable through paging, since the network is aware of the TAL of the device. When a CM leaves the group, based on its location, it determines whether location update is needed or not.

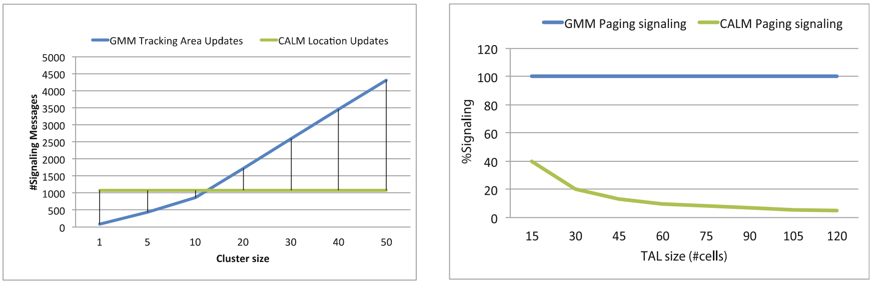
3 Performance Evaluation

In this section we present the evaluation outcomes of the assessment of the CALM solution that we propose against the Group Mobility Management (GMM) which has proven to be more efficient than 3GPP standards [5]. As described afore, CALM is triggered when the CH has selected to camp to a new eNB. Cell Reselection rate, cluster size and the Location Updates affect the performance of LM techniques and thus, in this section we measure the Location Update and Paging signaling overhead of the CALM solution for various scenarios with different cluster sizes, TAL sizes and Cell Reselection rates. Table 1 summarizes the assumptions of our analysis.

In Fig. 1(a) we present the way the cluster size affects the number of TAUs executed in the GMM mechanism and the messages sent in CALM. Since the traditional TAU does not have the same signaling messages as the Location update scheme we follow, the comparison was made based on signaling events triggered in each case, so as to have a common metric between our solution and the GMM mechanism. As shown in the figure our solution has fewer messages exchange for cluster size greater than 10 devices which is a rather small number taking into account the device density in 5G scenarios [18]. Such gains are achieved because in our solution when a device enters

Table 1. Parameter values for CALM assessment

Parameter	Assessment value
Cluster size	{1, 5, 10, 20, 30, 40, 50} nodes
TAL size	{15, 30, 45, 60, 75, 90, 105, 120} cells
Cell reselection rate	30 per UE/h [15]
Location update rate (for GMM [4])	1.2 per UE/h [16, 17]
Time window duration	3 h
Periodic location update timer T_{PLU}	56 min



(a) (b)

Fig. 1. (a) Location updates for various cluster sizes (b) Paging signaling

the group it deactivates all its Location Update procedures, while in the GMM mechanism the devices will still have their periodic TAU active. Thus, even for groups with rather small number of group members, our solution outperforms the GMM solution whereas for large numbers of group members, our algorithm achieves very significant gains.

Although, there are cases that our mechanism increases the signaling overhead for Location Update compared to the GMM solution (e.g., when having small clusters), in paging, the accuracy of our mechanism is always better, as the paging area is too restricted, while in GMM mechanism there is the need to page the whole TAL. Figure 1(b) below demonstrates the percentage of signaling reduction for paging procedure for various TAL sizes. The gains range from 60 % for small TAL size up to 95 % for very large TAL size. It is worth mentioning that our solution eliminates completely the possibility of page misses, due to the mobility context that is always up-to-date in the network. On the contrary, the GMM solution (as well as the other SOTA solutions) fails to avoid page misses, which may occur when a UE leaves a group, because the group maintenance is based on the periodic TAU of each device.

4 Conclusions

In this paper we have proposed a novel context-aware mechanism for efficient location management of groups of users/devices in wireless networks so as to reduce the overhead of the signaling channels. The method targets vehicular ad-hoc networks, machines, etc. but can also be applied to human-centric devices that move in groups (e.g., crowd movement). Our mechanism exploits already formed groups, for performing group based TAU. Thus, only one device (the cluster head) performs frequent TAUs on behalf of the overall group. This enables reduction on the TAU overhead and significantly precise paging compared to the state of the art solutions.

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