Qualitative and Quantitative Evaluation of MBMS Data Routing

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Abstract - **This paper studies several solutions to transfer MBMS data within the UMTS Core Network from the perspective of the B-BONE IST project. B-BONE aims at optimizing radio and network resource in broadcasting and multicasting over UMTS networks. The paper concludes some concern aspects in the qualitative analysis of the MBMS signalling proposal and evaluates several typical signalling proposals accordingly, and further compares the proposals in quantity by employing two mathematical models, the portable population model and the portable movement model**.

***Index Terms*— MBMS, UMTS, Core Network, Qualitative Analysis, Quantitative Analysis, Signalling**

I. INTRODUCTION

MBMS (Multimedia Broadcast/ Multicast Service)[3], a new service introduced in UMTS Release 6, strives to find a resource-efficient approach in UMTS (Universal Mobile Telecommunications System) networks to offer the service consuming high bandwidth such as the multimedia service from a single source to multiple receivers. Meanwhile, the B-BONE IST project [1], addresses many issues to optimize and manage radio and network resources for broadcasting/ multicasting in Packet Switched (PS) domains. Therefore, as an unsettled issue in MBMS, multiple solutions to transfer the MBMS data in the UMTS Core Network (CN) are studied in B-BONE and the paper gives a brief depiction.

In the paper, two most favourable solutions of the MBMS data path in the UMTS CN are explained in section II. Then the MBMS signalling proposals corresponding to the two solutions are studied. Some concern aspects in the qualitative analysis of the proposals are elaborated in section III. Two best candidates among all the considered proposals are described in section III as examples, and are further analysed in quantity in section IV. Finally the conclusion is drawn in section V.

II. SOLUTIONS OF MBMS DATA PATHS

The "selected RNCs" option and the "selected SGSNs" option in TR23.846 V.6.1.0 [2] (Figure 1) represent two most resource-efficient solutions among all solutions to transfer the MBMS data path in the UMTS core network [21]. In the "selected RNCs" solution, the data is sent fluently from the data source of a specific multicast service to selected RNCs (the RNCs serving the multicast members for the service) and not to all RNCs in the network, and then is sent from the RNCs to those members. In contrast, in the latter solution, the data is sent fluently from the data source to selected SGSNs (the SGSNs serving the multicast members) instead, and then is further delivered from the SGSNs to the multicast members via the RNCs.

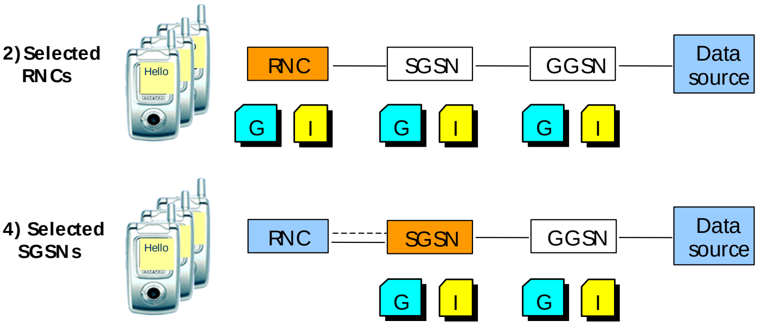

Figure 1: Two solutions for MBMS data paths

The difference between the two solutions could be abstracted as that, before the service data is transmitted, where group contexts and individual contexts are located and what contents are held by such contexts.

Group contexts and individual contexts are two new kinds of contexts introduced in MBMS and hold necessary info to construct the multicast distribution tree within the UMTS network. A group context is linked to a group of multicast members and implies the allocation of the resource for a shared Gn or Iu bearer; an individual context is linked to an individual multicast member and helps to ease the mobility management but doesn't lead to a dedicated bearer. A group context is always linked to all local individual contexts. Meanwhile, a group context may have different contents in different locations. If the group context is located in a non-leaf node of the multicast tree, since the tree diverges in upstream nodes, it should maintain the info of downstream nodes or similar info, and the data could be fluently forwarded from the non-leaf node to its downstream nodes. Oppositely, if the group context exists in a leaf node of the tree, it maintains no info of downstream nodes instead, and then the data has to stop in the leaf node and certain operation is required to set up the paths between the node and its downstream nodes to further reach the multicast members.

Therefore, as shown in Figure 1, in the "selected RNCs" option, selected RNCs are the leaf nodes, thus group contexts and individual contexts exist in the RNCs, the SGSNs and the GGSN, and the data could directly flow to the RNC. In contrast, in the “selected SGSNs” option, selected SGSNs are the leaf nodes, so that group contexts and individual contexts exist in the SGSNs and the GGSN, and the data stops in the SGSNs and can’t be relayed to the RNCs until the paths to the RNCs are set up.

A MBMS signaling proposal is required in all solutions of MBMS data paths in the CN to set up, maintain or remove specific MBMS contexts in involved network elements and to build necessary paths towards the multicast members. Multiple signaling proposals may support the same solution, among which only the best candidate demonstrates the maximum efficiency the solution could achieve. Hence, to better analyze the “selected RNCs” option and the “selected SGSNs” option, their corresponding signaling proposals should be further studied. Then the following two sections are dedicated to the qualitative analysis and the quantitative analysis of those MBMS signaling proposals respectively.

III. QUALITATIVE ANALYSIS

A. Concerned aspects in the qualitative analysis

Among many aspects in MBMS signaling proposals, the following aspects [11][12] are the most important ones.

1) *Network resource consumption*: How many network resources, such as dedicated or shared tunnels and specific MBMS contexts, group contexts and individual contexts, are required for a MBMS bearer service? Which network element (NE) possesses such two kinds of contexts? Do temporary idle bearers exist or not? How much processing overhead and communication overhead are demanded in each NE to construct shared bearers for MBMS multicast services?

2) *Group management*: To always maintain a cost-efficient local multicast tree within the UMTS network, the group management mechanism, initiated by the joining/ leaving request from multicast members for MBMS multicast services, focuses on creating, modifying or deleting the relevant group contexts and underlying shared tunnels to duly adapt to the change of the corresponding individual contexts. Thus, in the procedure, which NE handles the joining/ leaving request? Which NE decides the change of the group contexts and initiates relevant action? Will the SGSN and the GGSN communicate with each other just for individual contexts but not for group contexts?

3) *MBMS RAB set up*: To save network resources especially wireless resources, the MBMS RAB should be set up in the session start phase, but released in the session stop phase.

If a “Busy RA” and an “Idle RA” denotes a RA (Routing Area) serving multicast members or not for a specific MBMS multicast service respectively, and a “Busy RNC” and an “Idle RNC” have similar meanings, then the serving SGSN for the service may control both busy RAs and idle RAs, and a busy RA may contain both busy RNCs and idle RNCs. Obviously only the MBMS RABs from the serving SGSN towards the busy RNCs are useful for the service. However, SGSNs can only track UEs at the RA level; RNCs can only track UEs in the PMM-Connected state at the URA or the cell level [4][16] i.e. the RNC level. Therefore, how to identify the busy RAs and avoid useless MBMS RABs towards the idle RNCs, and how to efficiently set up MBMS RABs towards the UEs in the PMM-Idle state are main concerns of such procedure.

On the other hand, if the amount of the multicast members within a cell is below a threshold, the radio resources allocated for a MBMS p-mp (point to multipoint) RAB channel will exceed those required for multiple MBMS p-p (point to point) RAB channels [17], thus it’s more resource-efficient to adopt MBMS p-p RABs instead of MBMS p-mp RABs in the cell in this case. Hence the RNC initiates the counting phase to measure the number of the multicast members in each cell served by it. In addition, the RNC specific MBMS contexts also help the RNC make suitable decision about the MBMS RAB.

4) *Security and charging*: AAA (Authentication, Authorization and Accounting) mechanism should be considered to ensure authorized services are consumed by authenticated users with accurate charging data record for a specific MBMS service. Thus, in the procedure, which NE takes charge of the authentication and authorization of the multicast member joining the service? Which network node is involved in the charging for the service, and which kinds of contexts are adopted?

5) *Mobility management*: Similar as unicast services, in a MBMS multicast service, when a multicast members moves, it corresponding MBMS individual contexts should be forwarded from the old serving network element to the new one, and the relevant MBMS group contexts might be also modified to establish or release the relevant shared bearers when appreciate. In the study, it’s found that all the considered MBMS signaling proposals are very similar in the Mobility Management (MM) procedures, except the extra operation about RNC specific MBMS contexts required in the signaling proposals falling into the “selected RNCs” option. Hence the MM issue won’t be further discussed in the qualitative analysis.

B. All considered MBMS signalling proposals

As concluded in [21], for any MBMS signaling proposal, existing UMTS mechanisms about contexts and the mobility management should be reused; the GGSN should act as the only local multicast router within the UMTS network, and the local multicast tree should be kept isolated from the global multicast tree. In addition, the SGSN or the GGSN instead of the RNC could handle the group management. Namely, the RNC couldn’t receive the joining/ leaving request messages from multicast members and create/ delete individual contexts accordingly. Thus to maintain the RNC specific MBMS contexts, the SGSN should use certain signaling messages to notify the serving RNC to create/ delete local relevant individual contexts and modify local relative group contexts [5][7]. Such process is called UE linking/ de-linking, and the dedicated signaling messages are called the MBMS UE linking/ de-linking messages.

Hence, although eight MBMS signaling proposals (Table 1) are considered in the study, extra proposal 2 [10] is filtered out in advance since it uses the RNC to handle the group management. As a quite unclear proposal, option C [2] is also abandoned. The left six signaling proposals can be classed into two categories, supporting either the "selected SGSNs" option or the "selected RNCs" option. According to the qualitative comparison [21] in the aspects mentioned above, options A from TR23.846 v.6.1.0 [2] and TS from TS 23.246 v.6.6.0 [5] are recommended as the best candidates for each category, and will be briefly described in the following subsections as the examples of the qualitative analysis.

MBMS signalling proposals	Source	Comments
Option A Option B	TR23.846 v.6.1.0 [2] TR23.846 v.6.1.0 [2]	Selected SGSNs
Option E Option G Extra proposal 1 TS	TR23.846 v.6.1.0 [2] TR23.846 v.6.1.0 [2] [19] TS 23.246 v.6.6.0 [5]	Selected RNCs
Extra Proposal 2 Option C	[10} TR23.846 v.6.1.0.[2]	abandoned

Table 1: All considered MBMS signalling proposals

C. *Option A: best candidate for "selected SGSNs"*

1) *Network resource consumption*: Single shared Gn bearers and shared Iu bearers of MBMS RABs are built for MBMS multicast services. MBMS group contexts are created in both the serving SGSN and the serving GGSN, but MBMS individual contexts are only created in the serving SGSN. However, neither MBMS group contexts nor MBMS individual contexts exist in the RNCs.

Therefore, in this proposal, the costs to maintain RNC specific MBMS contexts are saved, especially when multicast members move frequently. However, the lack of such contexts asks more multicast members to give the counting response in the MBMS RAB set up procedure compared to the signalling proposals in another category such as TS, which increases the relevant signaling costs.

2) *Group management and AAA*: The SGSN receives and handles the joining/leaving request from multicast members. Not the GGSN but the SGSN determines to create/delete the couple of group contexts and the tunnels between the SGSN and the GGSN, and the GGSN decides when to join/ leave the global multicast tree. Furthermore, the SGSN takes charge of the authentication and authorization of multicast members, and no individual contexts exist in the GGSN for the charging.

In option A, multicast members don't communicate with the GGSN directly. Oppositely, the serving SGSN converges its served multicast members' desire to join or leave certain multicast service, and only communicates with the serving GGSN when necessary. The GGSN also converges its served SGSNs' desire to join or leave the global multicast tree for the service. Thus the GGSN is only involved in the procedure when appropriate. In contrast, in the proposals supporting another category, the GGSN always acts whenever a multicast member joins/ leaves the service. As the amount of the serving SGSNs and that of the multicast members served by the same GGSN are in different magnitude, at this point, the hierarchical processing of the group management info in option A greatly lessens the load on the GGSN compared to all proposals in another category.

However, the AAA mechanism adopted in option A is beyond the ability of current standards. In normal PS services, it's the AAA server inside or outside the PLMN to authenticate and authorize the UE for a PS service [8], and the GGSN instead of the SGSN acts as the client of the AAA server. Meanwhile, PS services' charging data is collected per UE per service by the aid of PDP contexts, one kind of individual context, in both the SGSN and the GGSN [9]. The lack of GGSN MBMS individual context makes such charging mechanism hard to be migrated into MBMS services. Therefore, although option A has certain benefits, it might be difficult to be deployed.

3) *MBMS RAB set up*: In option A, the least intelligence is required in the serving SGSN among all considered signaling proposals, as the processing overhead in SGSNs to identify busy RAs is saved. Meanwhile, multicast members in PMM-Idle or in PMM-Connected are handled at the same time. Nevertheless, those benefits are at the cost of the flooding of certain signaling messages and the creation of the most temporary idle Iu bearers. When the service data is coming, the serving SGSN notifies all RNCs connected to it. Each informed RNC then notifies all UEs served by it, and sets up Iu bearers of MBMS RABs between the RNC and the SGSN, whether the RNC serves multicast members or not. In addition, since no specific MBMS contexts exist in the RNC so that the RNC has no knowledge of local multicast members, all local multicast members should give the counting response to the RNC for setting up cost-efficient MBMS p-p or p-mp RABs, which further increases signaling costs.

D. *TS: best candidate for "selected RNCs"*

1) *Network resource consumption*: Single shared Gn bearers and shared Iu bearers of MBMS RABs are employed to support MBMS multicast services. Both MBMS group contexts and individual contexts exist in the GGSN, the SGSN and the RNC. The RNC specific MBMS contexts help to decrease the signaling costs required to set up MBMS RABs, but the costs to maintain such contexts have to be spent, especially when multicast members move frequently.

2) *Group management and AAA*: The existence of GGSN MBMS individual contexts imply that the SGSN should communicate with the GGSN for both MBMS group contexts and individual contexts. Thus in TS, two kinds of dedicated messages are employed. Similar as option A, the messages about group contexts and shared bearers are exchanged between the SGSN and the GGSN when necessary, while the SGSN is the decision-maker. Meanwhile, the messages about individual contexts are exchanged between the SGSN and the GGSN, whenever a multicast member joins/leaves the service. Since the

GGSN is always involved in such procedure, it has a heavier load in TS compared to option A.

Although GGSN MBMS individual contexts bring more signaling costs in TS compared to option A, however, as one kind of special PDP contexts, they ease the charging problem. Furthermore, the security problem in option A is also solved, since in TS complying with current standard, the GGSN acts as the client of the AAA server. In such proposal, the GGSN handles the group management and receives IGMP joining or leaving messages issued from a multicast member, and then ask the AAA server to authenticate and authorize the member. Hence, AAA isn't a drawback anymore in TS.

One point must be mentioned. In the group management procedure, although option A shows a general lower signaling cost compared to TS, it should be modified to adapt to current AAA mechanism. I.e., the relevant costs of option A in such procedure such as the joining cost and the leaving cost are insufficient. As option A can be modified according to TS, we assume no cost differences between option A and TS in such procedure.

3) *MBMS RAB set up*: To set up MBMS RABs towards the multicast members in PMM-idle for a incoming MBMS multicast service, in TS, the SGSN informs all connected RNCs the info concluded dispersedly before the session start, the lists of RAs with the multicast members in PMM-idle. Together with the info offered by the local individual contexts related to the members in PMM-Connected, the RNCs set up the MBMS RABs towards the members in PMM-Connected or in PMM-Idle at the same time, and the members in certain RRC states [6] needn't give the counting response. However, in TS, the Iu bearer of the MBMS RABs are still set up towards all RNCs serving the busy RAs, which results in some temporary idle Iu bearers, although the amount of such bearers is less than that of option A.

IV. QUANTITATIVE ANALYSIS

The quantitative analysis between option A and TS, two best candidates among the signalling proposals supporting either the "selected SGSNs" option and the "selected RNCs" option, focuses on the cost analysis. But as analyzed in [21], since only the session start cost differences and the mobility cost differences between option A and TS are significant among all relevant costs, only *the session start cost* and *the mobility cost differences* are further analyzed in quantity.

The session start cost covers the costs happening in the MBMS RAB set up procedure. As describe before, the Iu bearers of the MBMS RABs for a specific MBMS multicast service are set up by all RNCs serving the busy RAs and idle RAs controlled by the serving SGSN in option A, but only be set up by the RNCs serving the busy RAs in TS. In addition, all multicast members for a multicast service should give counting response in option A but only those members in certain RRC states [6] need to respond in TS. To calculate *the session start cost* of a specific proposal, the scope of involved entities should be identified and appropriate models should be applied.

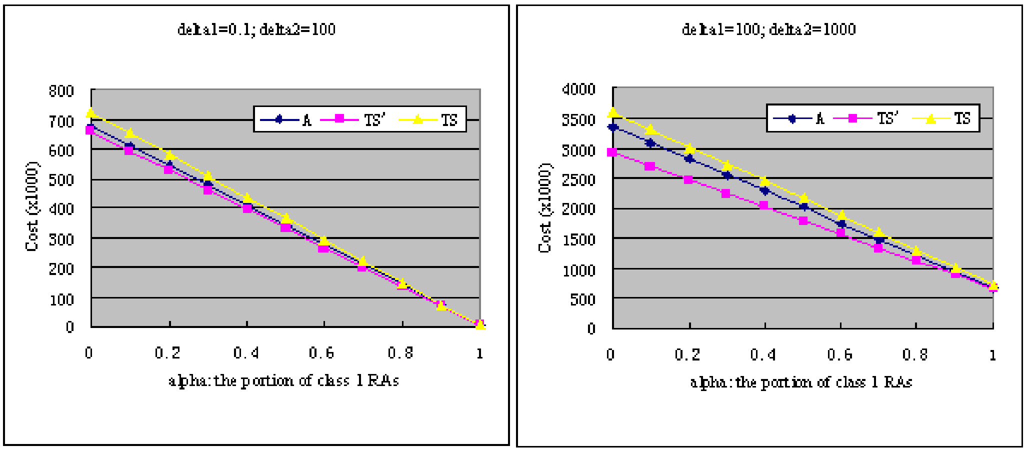

Figure 2: Effect of portion of Class 1 Routing Areas (α) on the cost

TS requires extra mobility cost to maintain RNC specific MBMS contexts compared to option A. Namely, when a UE move across a sub RA, the area in a RA controlled by a RNC, the corresponding specific MBMS contexts should be created in the new serving RNC (linking) and deleted from in the old serving RNC (de-linking). For such function, TS can use the explicit UE (de)linking, i.e., the SGSN issues the MBMS UE linking/de-linking messages to the new/old serving RNC respectively, and *the mobility cost differences* between option A and TS per UE (multicast member) are the transmission costs of the dedicated signaling messages multiplied by the average numbers of sub RAs that the UE moves across. TS can also use the implicit UE (de)linking instead. Namely, the UE linking/ de-linking info is embedded into existing mandatory mobility-related signaling messages, so that the transmission costs of the dedicated signaling messages are saved. To simplify the calculation, *the mobility cost differences* between option A and TS in this case are supposed to be decreased to zero.

The portable population model [14][15][18][19], a model about the steady state mobiles' population within an area such as a cell, a LA (Location Area) or a RA (Routing Area), helps to quantify the amount of involved entities in a signaling proposal and calculate *the session start cost*. The portable movement model [13][14] shows how to calculate the average number of RAs (sub RAs) the UE moves across, which is necessary to calculate *the mobility cost differences*. Based on such two kinds of models, with the value of the transmission costs of wired or wireless links and the process costs in network elements set according to [19][20] and certain parameters of the network configuration [19], the total costs of option A and TS with explicit or implicit UE (de)linking (denoted by TS and TS' respectively) are calculated. Figure 2 shows an example of the quantitative analysis.

Provided that all RAs in a UMTS network belong to 2 different categories with different traffic intensity i.e. the expected amount of multicast members for a specific MBMS multicast service in a RA, δ1 or δ2 respectively, small or big value of δ1 or δ2 will imply a RA with low or high population for the service, and MBMS p-p RABs or p-mp RABs should be set up within the RA. Thus we will analysis the cost based on two typical scenarios, (δ1 = 0.1, δ2 = 100) and (δ1 = 100, δ2 = 1000). In the first scenario only MBMS p-p RABs are set up in the network but in the second scenario both MBMS p-p and p-mp RABs are set up. Meanwhile, α denotes the portion of category 1 RAs in total RAs. If α is close to 0, almost all the RAs in the network belong to category 2; if α is close to 1, an opposite extreme case will happen. Therefore, different value of α, δ1 and δ2, could simulate different practical case.

Thus, as shown in Figure 2, with the basic value, in both scenarios, the cost of option A and TS with explicit or implicit (de)UE linking all decrease as α increases. In addition, the cost of *option A* always exceeds that of *TS with implicit UE (de)linking* irrespective of the specific scenario and the value of α, while the cost of *TS with explicit UE (de)linking* surpasses that of *option A* with maximal approximate 7% increase nearly in all case. As *option A* also brings more temporary idle Iu bears, *TS with implicit UE (de)linking* is more favorable than *option A*, and *implicit UE (de)linking* instead of *explicit (de)linking* should be used to handle the mobility of multicast members.

V. CONCLUSION

According to the qualitative analysis, both the "selected RNC" option and the "selected SGSN" option represented by their corresponding signalling proposals hold certain pros and cons. To make better evaluation, a quantitative analysis is also conducted on the two best candidates supporting each category, respectively, and both benefits and drawbacks of each candidate can be found again. Namely, the "selected RNC" option especially with optimized signaling (*implicit UE linking/de-linking*) requires less signaling overhead than the "selected SGSN" option especially for the multicast members with low mobility. But the "selected SGSN" option may outperform the "selected RNC" option for the multicast members with high mobility. As different value set for calculation may lead to different result, for a more accurate comparison, the value should be reset according to the results of actual measurements or simulations, and the signalling proposals should be further studied accordingly.

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