Context-aware Multimedia Distribution to User Groups

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Abstract — **Increasingly, multimedia services require efficient delivery systems to support content distribution. If a service targets groups of users then a point-to-multipoint distribution technology is naturally more optimized. 3GPP has specified MBMS (Multimedia Broadcast Multicast Service) and E-MBMS (Evolved MBMS) systems to broadcast and multicast rich media contents to mobile communities in an efficient way. But these systems can be enhanced with a permanent access to users' context information for dynamic group management leading to effective content distribution. This paper proposes an algorithm that employs the ubiquitous awareness of the user situation to optimize the multimedia content distribution to user groups, saving the resources of the mobile operators' networks.**

Keywords: Context-awareness, Ubiquitous Information Appliance, E-MBMS, MBMS, Efficiency, User Groups.

I. INTRODUCTION

The new multimedia trends are forcing mobile operators to improve their content distribution processes in order to avoid network collapses. Mobile TV services and the social network fashion are just two examples that require efficient networks to enable the rich media content distribution to mobile communities.

Multimedia services are by nature major resources consumers; therefore 3GPP has launched MBMS (Multimedia Broadcast Multicast Service) and E-MBMS (Evolved MBMS) to enable the point-to-multipoint transmissions over UMTS (Universal Mobile Telecommunication System) and EPS (Evolved Packet System) networks in an efficient way [1]. This allows saving network resources because users share the channels used on the multimedia distribution.

The MBMS and the E-MBMS systems can be evolved by considering users' context information on the bearers' management, which leads to an improved data distribution. The ubiquitous knowledge of users' instant situation allows the systems to perform their tasks more accurately. This can be achieved by splitting groups of users intending to receive the multimedia content into several subgroups encompassing the users under the same situation. For the same content distribution, each subgroup will include all the users receiving the content with the same format consuming the same network resources. An example of splitting a group into two subgroups can be seen in Figure 1.

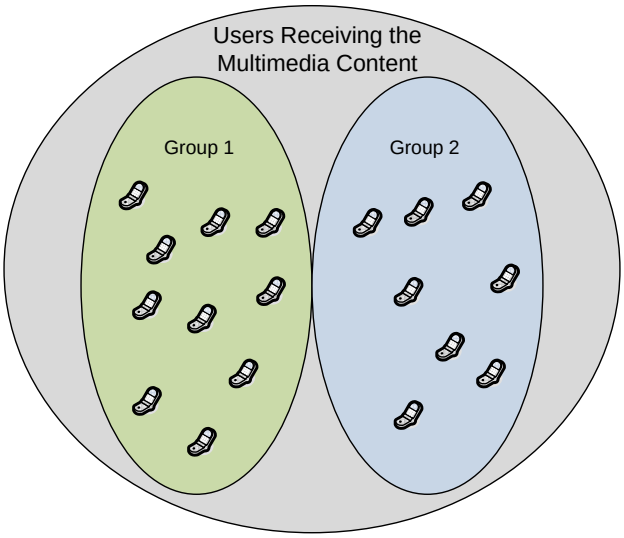

Figure 1 - User Groups Splitting

This paper proposes an algorithm that enables a context-aware MBMS and E-MBMS (CE-MBMS) system to dynamically create several subgroups based on a ubiquitous knowledge of the users' situation leading to an effective multimedia content distribution. A CE-MBMS system is for sure a stepping stone in the direction of an efficient multimedia delivery over mobile networks to user groups.

The rest of the paper is organized as follows: in Section II it is described the main motivation for the work carried out; Section III describes several related publications; the proposed algorithm to improve the network efficiency is detailed in Section IV; Section V presents the main results of the work performed; finally, Section VI summarizes the main conclusions.

II. MOTIVATION

The increase video trend with powerful formats, such as 3D, and the unlimited social networks tendency make us believe that in a near future there will be a lot of services targeting groups of users. These services will generate a huge amount of traffic that requires systems skilled to efficiently deliver the multimedia contents. When the distribution is to be made to groups of users, a point-to-multipoint technology is much more effective. MBMS and E-MBMS are the technologies that can support an efficient multimedia content

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distribution to mobile communities. Still, they can be evolved with context information to enable a personalized delivery. Therefore, the main motivation of this paper is to enhance the process of content distribution using the user situation knowledge on the CE-MBMS channel management. A service scenario is proposed in order to facilitate the demonstration of the algorithm efficiency.

A. *Context-aware User Groups*

The solution to offer personalized services over optimized networks to groups of mobile users is sustained by the mechanisms to manage the groups' splitting process. For the MBMS and the E-MBMS cases the final groups maps on specific content formats that are to be used on the multimedia distribution to mobile communities by means of shared channels. Therefore, each subgroup having several end-users will be matched with a specific format arrangement. The group creation shall take into account all ubiquitous context information, which may encompass environmental information, network status, user profile, operator policies or terminal capabilities, as shown in Figure 2.

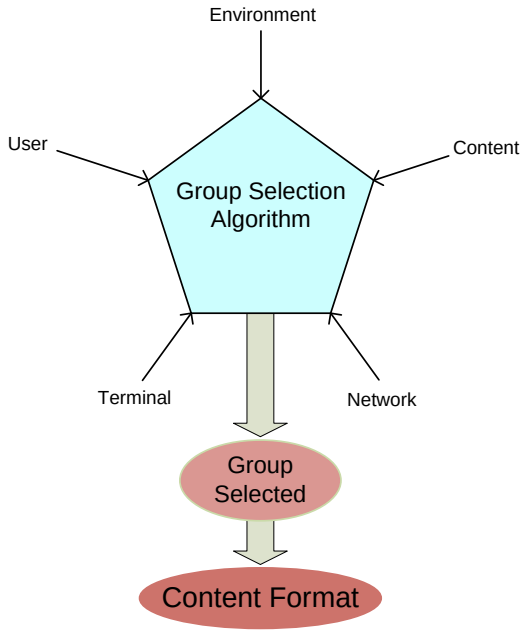

Figure 2 - Context Impacting the Group Selection Process

Consequently, this paper presents an algorithm that is devised to allow a CE-MBMS system to optimally deliver its multimedia contents to user groups. Significant efficiency gains can be achieved by personalizing the contents through the group splitting process by making use of a ubiquitous context information access.

B. *Service Scenario*

Maria really loves football. She is always following her team matches. For that, she has subscribed the mobile service "I am a fan", which replays the goals and the main plays almost on real-time. Depending on Maria's environment, the service will adapt the content to be transmitted. The service also considers the Maria's profile for the content adaptation.

Whenever there is a new goal or highlight to be transmitted related with the match still running the system shall check if Maria is on a noisy environment and if she is on the move; plus it shall also take into account which team has scored. With all this information, the service will tailor the content in the format that best fits the Maria's situation, improving the system effectiveness while ensuring a high level of user satisfaction.

III. RELATED WORK

The association between context information with mobile networks is now a hot topic in the scientific community. It allows the introduction of personalized services running on top of improved networks.

The work presented in [2] devises a context-aware framework for content delivery in pervasive computing environments. It is here proposed the adaptation of multimedia content to the specific user situation. The framework supports media coding and transmission adaptation taking into account temporal, spatial, and communicational circumstances of the user.

The work carried out in [3] has tackled the impact of context, sensors and wireless networks in the telecommunications field. It has proposed several scenarios stressing the potential synergies between the defined areas.

In [4] was demonstrated that mainly in an MBMS environment, "there is an advantage for using more efficient codecs, by sub-grouping multicast groups based on supported codec, as they become widely available in the network". A hierarchal group management framework was proposed allowing the control of transcoding based groups.

The work carried out in [5] introduces a framework that allows the network to control its devices connectivity based virtually on any criteria. The paper proposes an algorithm to intelligently manage the device mobility, which can take into account any type of information, such as context, user preferences or user profiling.

The work presented in [6] defends the service enrichment by means of context usage. It presents an innovative service based on different enablers, over an IMS (IP Multimedia Subsystem) environment, responsible for managing triggers defined by the users.

The main concern of the work presented in [7] was to research the prerequisites and enablers for context-aware services. Furthermore, it has highlighted the challenges and the priorities for future investigations in the context-awareness area.

The applicability of context-based multicast content distribution was investigated in [8] on the example of a Swiss shopping centre where push and video-based mobile advertising services were selected as a use case scenario.

In [9] is devised an architecture "where context information is taken into account to improve MBMS and E-MBMS services". The proposed architecture makes possible an efficient multimedia content distribution to mobile users' communities.

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The research presented in [10] considers the use of context information to achieve a personalized multiparty multimedia content delivery to groups of users. It describes an architecture that encompasses mechanisms for context management, content processing and distribution to mobile communities.

IV. PROPOSED MECHANISM

The following sections describe and present the devised mechanism for user group selection.

A. Ubiquitous Content Delivey

Here, it is devised a mechanism that considers a set of stages where the user situation is evaluated. Each piece of ubiquitous context information is assessed and, depending on the results achieved, a classification is provided to each possible group. At the end, the group selected is the one with the highest classification, which enables an effective multimedia content distribution.

As an example, consider the Figure 3 illustration where two different groups are taken into account: G1 encompassing all clients using a high definition codec and G2 for users having only access to a low definition codec. Users on the move have no advantage of being associated with G1 since they won't be under an appropriate environment where they can enjoy the full multimedia quality provided by a high definition codec. Therefore, its employment is not recommended for moving users. However G2 could be a good option for clients on the move, since they can enjoy the service with about the same experience as using G1, but saving network resources. Consequently, the G2 classification can be marked as Good. Similar logic can be applied when users are stopped, but, in this case, leading to opposite classifications: users clogged can make use of a higher definition codec; therefore G1 shall be better scored than G2.

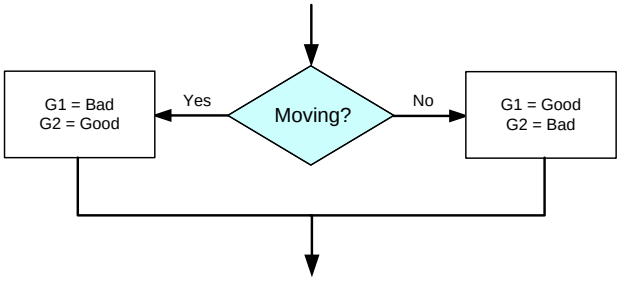

Figure 3 - Group Selection for a Moving User Scenario

The choice of the group may also be dependent on the type of environment that surrounds the client. A user placed in a quiet environment can, undisturbed, enjoy the multimedia data using a high definition content format. Therefore, G1 is a very good option for this client while G2 could be a less than remarkable option since it will decrease the user experience. In the opposite case, a client in a noisy environment, the group classification shall be the contrary: G1 is a bad choice since the noise would disturb the user experience while G2 could be a good option. This can be seen in Figure 4.

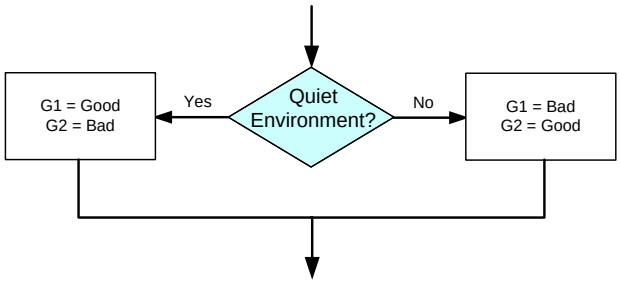

Figure 4 - Group Selection for a Quiet Environment Scenario

Since there is an endless set of context information related with users' situation, mobile operators shall narrow down the context data by selecting only the ones useful for improving the service and the multimedia distribution.

B. Proposed Mechanism

The mechanism here proposed for group selection manages a set of stages where the occurrence of a specific context event is evaluated, which leads to a specific group classification. Furthermore, it makes possible the easily addition and subtraction of context information in the chain. After running all the steps, the user is finally considered as belonging to a specific group. All the process can be seen in Figure 5.

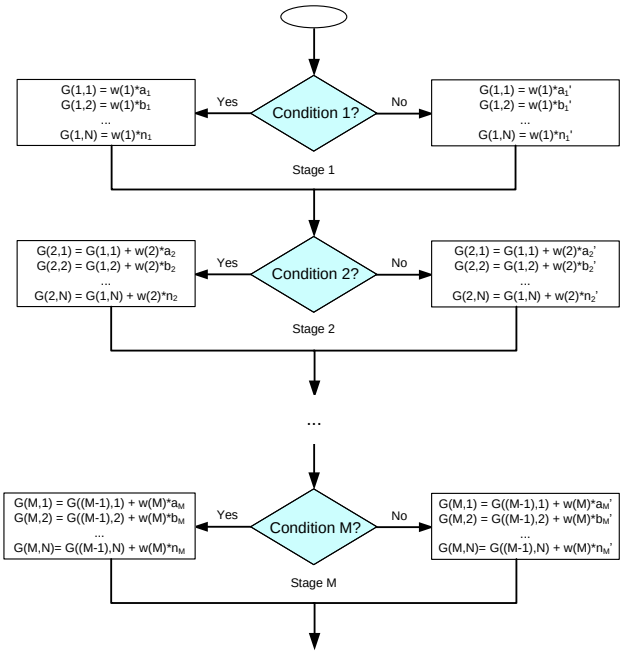

Figure 5 - Context-aware Group Selection

Consider G(i,j) as the total classification allocated in stage i to the Group number j, where:

$$i \in [1, M]$$
$$j \in [1, N]$$
$$i, j \in \mathrm{N}$$

Note that M is the number of stages, or conditions, while N represents the number of possible groups.

Consider also that w(i) represents the weight of the i^{th} condition on the group selection process, where:

$$w(i) \in]0,1]$$

Additionally, c(i,j) can be defined as the j^{th} group classification at stage i, where:

$$c(i, j) \in [1,100]$$

There are some conditions that are mandatory to happen in order to allow the mapping of a specific user in a specific group. For instance, it is mandatory the support of the content format by, at least, the terminal, the network and the source. Furthermore, the user profile shall allow the client the codec usage. Consequently, the following multiplicand shall be also taken into account:

$$\prod_m S(m, j)$$

Where S(m,j) is m^{th} mandatory condition required to allow the user mapping in the j^{th} Group. It takes the value 0 if the mapping is not possible and the value 1 if it is supported.

$$S(m, j) \in \{0,1\}$$

Consider T defined as a vector representing the total classification of each of the N^{th} possible groups for the CE-MBMS service. Furthermore, j can be defined as the index of the j^{th} group classification belonging to the T vector.

Consequently, T(j) can be defined as:

$$T(j) = \prod_m S(m, j) * \sum_i (w(i) * c(i, j)), \forall j \in [1, N]$$

This is equivalent to the following equality:

$$T(j) = \prod_m S(m, j) * G(M, j)$$

The result will be a list of the group relative importance for a user in a specific service, where the highest value means the "best" one. As can be seen by the expression above, the unavailability of the content format in the terminal, network, or source prevents its choice in the group selection procedure since it assigns a zero value. The selected group is obtained by finding the index of the T element having the highest value. Using the "Matlab" notation, the GroupSelected can be obtained in the following way:

[value,index] = max (T) ⇔

GroupSelected = index

In a match case, when two different groups end with the same classification, the network can be configured to randomly allocate a user to one of the defined groups or it can apply specific rules refining the group selection.

This approach enables operators to allocate users in specific groups based on context information leading to useful services delivered over optimized networks.

V. EVALUATION

The scenario environment and its evaluation are presented in the following sections.

A. Scenario Environment

The scenario depicted for the proof of concept considers sets of users in different environmental conditions accessing their multimedia services. To demonstrate the benefits of the group selection procedure it was developed a simulation environment where 450 users were randomly spread in the network encompassing 15 antennas having each of them 3 sectors. It was considered two users' groups where the first group uses a higher definition codec that consumes twice the data rate of the second one. The users were accessing their services utilizing either a 256 kbps (Group 1) or a 128 kbps (Group 2) content format. Besides the comparison between the mean data rate of the service accesses using the CE-MBMS system running or not the proposed group selection algorithm it was also considered using unicast technology with and without the group selection procedure active. It is assumed that when the group selection procedure is switched off the system chooses whenever possible the 256 kbps content format to distribute the multimedia content to the end-users. The group selection was done based on the users' movement, on the existing noise in the users' surroundings, and on the user profile. Table 1 presents the group classification according to the user context.

Table 1 – Group Classification

User Context	**Group Classification**			
	Yes		***No***	
	G1	***G2***	***G1***	***G2***
Content match the user profile	90	10	10	90
User in a quiet environment	90	10	10	90
User on the move	10	90	90	10

It was considered that each condition has the same weight in the group selection process. Moreover, it is assumed that 90% of the terminals are capable of using the high definition codec. Additionally, for the analysis of performance it was considered different percentages of fans depending on where the game took place. Finally, it was crossed over with specific team statistics taken from [11], which leads to different team scores' probabilities. Multiple runs of the scenario were executed.

B. Scenario Evaluation

1) Group Selection Results

Two environments are here considered to demonstrate the group selection results: a vehicular scenario where users have a higher probability of being on move and facing a noisy environment; and a city centre situation having users mostly stationary in a much quieter atmosphere.

Best Team Playing at Home

These simulations assume that the best team plays at home. This has two implications: most of the users in the area are supporters of the best team and the best team has even a higher probability of scoring. Consequently, most of the contents made available by the service match the user profiles.

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Figure 6 presents the relative data rate transmission per antenna in a vehicular environment. As can be there observed the group selection procedure operation provided efficiency to the system even when using point-to-point connections, where mobile operators can save almost 34% of data rate transmission in comparison with the raw unicast. The utilization of the group selection on the CE-MBMS leads to almost 5% of gains regarding the standard E-MBMS. This is due to the fact that in some situation where users face a noisy environment while on the move the selected group is the one with the lowest data rate since the decrease of the quality does not affect the user experience. Considering now the two extremes' cases, the CE-MBMS operation can decrease the total data rate up to 85% when comparing it with the unicast transmission without the group selection procedure active.

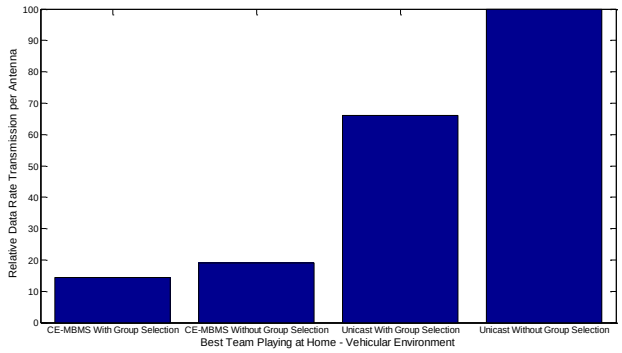

Figure 6 - Best Team Playing at Home in a Vehicular Environment

It was taken for granted that in a city centre environment most of the users are still and consequently they can face a calmer ambience than the one existing in vehicular situations. Figure 7 shows the relative data rate transmission per antenna in a city centre location. As can be seen, the group selection procedure leads to an improvement of almost 13% of the total data rate in the unicast transmissions. The savings go up to 4% when assessing the group selection utilization in the CE-MBMS systems.

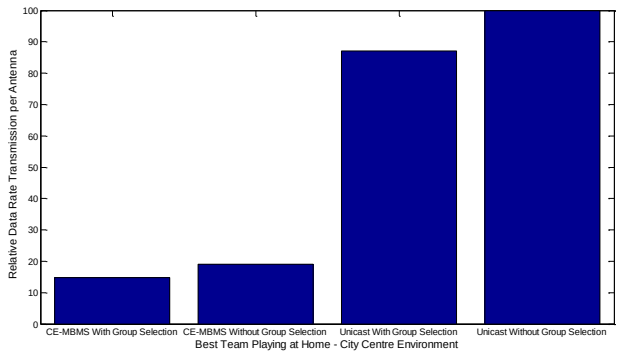

Figure 7 - Best Team Playing at Home in a City Centre Environment

It can be noted an efficiency decrease when going from a vehicular to a city centre scenario. This happens due to the assumption that users located in the city centre can easily sit in a quiet place to access their multimedia services. Thus, the system tends to put most of the users in a same group all enjoying higher data rates content formats, in the end increasing the system total data rate consumption.

Weakest Team Playing at Home

The following simulations assume that the weakest team plays at home. Therefore, most of the supports are fans of the worst team, which has a lesser probability of scoring.

As can be observed in Figure 8, the relative data rate transmission per antenna in a vehicular environment decreases with the introduction of the group selection algorithm. The data rate savings for the service can reach up to 37% when comparing the unicast transmissions running the procedure with the raw unicast multimedia delivery. Furthermore, when comparing to the standard E-MBMS, the use of the group selection algorithm on the CE-MBMS makes possible to save up to 5% of the utilized resources. These gains can reach up to 72% when comparing with basic unicast transmissions.

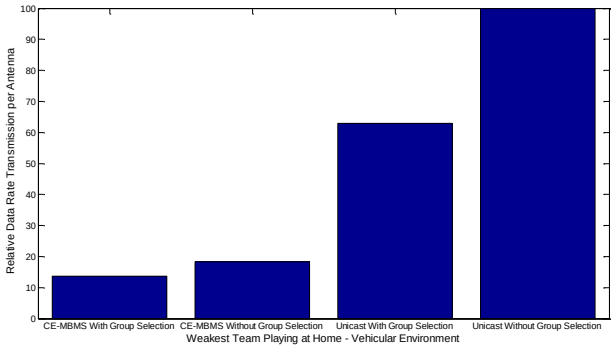

Figure 8 - Weakest Team Playing at Home in a Vehicular Environment

The results presented in Figure 9 are related to a city centre environment where the weakest team is the home team. As expected the unicast transmission using the group selection algorithm consumes fewer resources than the ones transmitting with the standard unicast, being the data rate savings about 16 % of the total data rate needed when transmitting with the raw unicast. Furthermore, the use of CE-MBMS allows up to 85 % of data rate transmission reduction when having as a reference the unicast transmission without group selection, which is a very significant gain.

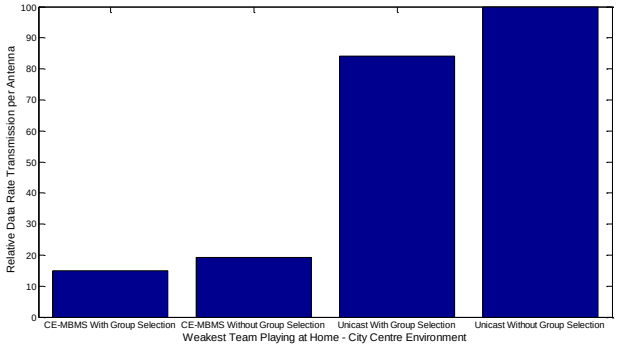

Figure 9 - Weakest Team Playing at Home in a City Centre Environment

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2) Number of Users per Group

Figure 10 presents the relative users' groups distribution in different environments. Users in Group 1 consume 256 kbps multimedia content while users in Group 2 access their services requiring a 128 kbps connection. Considering the weakest team as the reference, the following assumptions shall be taken into account:

- CH: the weakest team is playing at Home in a City centre environment
- CV: the weakest team is the Visitor in a City centre environment
- VH: the weakest team is playing at Home in a Vehicular environment
- VV: the weakest team is the Visitor in a Vehicular environment

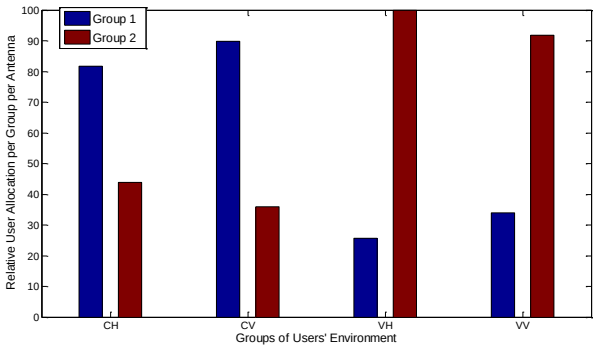

Figure 10 - Users' Distribution per Group

The users' groups' distribution are deeply affected by the type of environment. It can be seen that users in the city centre are typically allocated to Group 1 while users placed in a vehicular environment are included in Group 2. This happens mainly because the users' classification considers that clients on the move or on noisy environments cannot enjoy higher definition formats, pushing them to the lowers data rate transmissions, making it possible to save network resources.

It can also be noted that it is not indifferent to play the game as a visitor or at home. Home teams have a larger supporter base, therefore, when their team scores there are much more fans pulled to the higher quality videos. Consequently, it can be seen that for the same environment, city centre or vehicular, the number of users allocated to Group 1 increases whenever the weakest team plays in the adversary field.

VI. CONCLUSION AND FUTURE WORK

The dynamic group selection procedure is a powerful tool that mobile operators can use to offer personalized services over improved networks to groups of users. The users' group selection is made based on a ubiquitous access to their clients' situation data. Mobile operators shall make the appropriate tuning taking into account selected environment information in order to optimize its operation. The results here presented have demonstrated its usefulness where significant gains were shown with the CE-MBMS usage. The selected proof of concept scenarios gave almost 5% of gains when comparing with the standard E-MBMS and they can reach up to 85% of data rate reduction when comparing with the raw unicast transmission.

As future work it is envisage the study of the user satisfaction taking into account the involved dynamics of a context-aware bearer modification. For that, a testbed will be setup where users can access the multimedia contents under different situations and where they can provide their experience feedback according to their situations.

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