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International eJournals

ISSN 0976 – 1411

INTERNATIONAL eJOURNAL OF MATHEMATICS AND ENGINEERING

www.InternationaleJournals.com

International ejournal of Mathematics and Engineering 197 (2012) 1881 - 1888

Multicast and Broadcast Service with high Quality of Service on Mobile Communication Networks by Dynamic Channel Allocation

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ABSTRACT: The Multicast and Broadcast Service Zone technology is proposed in Mobile Communication Network standards to improve system capacity and reduce handoff delay for wireless MBS calls. In the MBS zone technology, a group of BSs form an MBS zone, where the macro diversity is applied in the MS, the BSs synchronize to transmit the MBS content on the same common channel, interference caused by the common channel is reduced, and the MBS MSs need not perform handoff while moving between the BSs in the same MBS zone. However, when there is no MBS MS in a BS with the MBS zone technology, the transmission on the common channel wastes the bandwidth of the BS. In wireless Multicast Broadcast Service, the common channel is used to multicast the MBS content to the Mobile Stations (MSs) on the MBS calls within the coverage area of a Base Station (BS), which causes interference to the dedicated channels serving the traditional calls, and degrades the system capacity. It is an important issue to determine the condition for the MBS Controller (MBSC) to enable the MBS zone technology by considering the QoS for traditional calls and MBS calls. In this paper, we propose two Dynamic Channel Allocation schemes: DCA by considering the condition for enabling the MBS zone technology.

Keywords: Dynamic Channel Allocation, Multicast Broadcast Service with high QoS, MCN

I. INTRODUCTION

The system capacity improvement and reduce the handoff delay for wireless Multicast and Broadcast Service (MBS), the MBS zone technology is being proposed in several Mobile Communications Network (MCN) standards, such as IEEE 802. 16-2009 [1], Enhanced MBS Zone in IEEE 802. 16m [2], and Multimedia Broadcast multicast service Single Frequency Network Area in 3GPP Universal Mobile Telecommunications System (UMTS) and Long Term Evolution (LTE). Figure 1 illustrates the general MCN architecture with the MBS zone technology. The MBS Controller (MBSC; Figure 1 (3» accommodates the functionalities including the MBS zone management, service announcement, membership management, security management, session management, session transmission, multicast connection identifier and IP address management.

For more details of the functionalities, readers may refer to [4]. The MBS Server (Figure 1 (1» is the MBS content provider. The Multicast Router (Figure 1 (2» performs multicast routing (e.g., IGMP and PIM-SM) for the MBS content in the IP network.
Two types of logical channels (including common channel and dedicated channel) are used to transmit the MBS content.

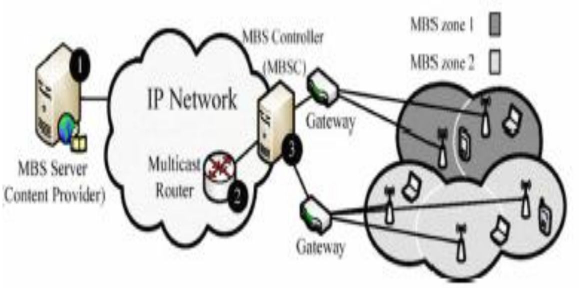


Fig. 1. The MCN architecture with the MBS zone technology

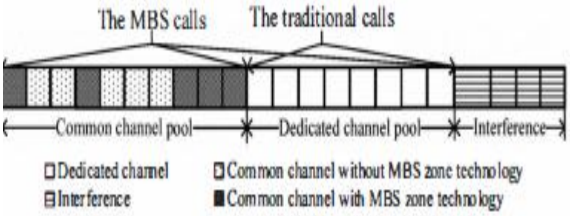


Fig. 2. The logical channel pool of a BS

Figure 2 illustrates the channel pool consisting of common channels and dedicated channels. The transmission of a dedicated channel is point-to-point between the Base Station (BS) and the Mobile Station (MS), which serves either an MBS call or a traditional call (i.e., unicast packet-switched or circuitswitched call). The transmission of a common channel is point-to-multipoint between the BS and a group of MSs. The common channel can be used to multicast the MBS content to all MSs subscribing the same MBS in the coverage area of the BS (known as the cell). Compared with the dedicated channel, there is no associated control channel for the common channel to report the channel quality of the MS. To cover the whole cell, the transmission power of a common channel should be large enough. Therefore, the usage of a common channel may result in higher interference to the dedicated channels. It is recommended to use a common channel to deliver the MBS content while the number of MSs listening to the MBS content is sufficiently large. In the MBS zone technology, an MBS zone consists of a group of BSs synchronized to transmit the same MBS content using the same common channel. In the overlapped area of two or more BSs, the signals on the same common channel of different BSs can be aggregated at the MS (known as the macro diversity [I]). As pointed out in the studies, the transmission power required for a common channel with the MBS zone technology is less than that without the MBS zone technology due to the macro diversity, and the interference caused by the common channels is reduced Suppose that it damages dz and de (where dz :::; de) dedicated channels to turn on a common channel with the MBS zone technology and without the MBS zone technology, respectively. The analysis of the values for dz and de is out of the scope of this paper, and readers may refer to for more details. The channel allocation scheme of the standard MBS zone technology (namely scheme Basic) is described as follows. To simplify our discussion, we assume one MBS service in the MBS network, and assume that there are K cells in Z, and Z = {Celh , Cell2' ... , CellK-l ' Cells}. Suppose that an MS currently resides in Cells. For Z, the variable zone is maintained in the MBSC. The zone = enabled (zone = disabled) indicates that the MBS zone technology is enabled (disabled) in Z. Scheme Basic consists of six procedures: Service Flow Creation (SFC), Service Flow Deletion (SFD), Procedure Service Join (PSJ), Procedure Service Leave (PSL), intra-MBS zone handoff, and inter-MBS zone handoff.

To make a traditional call, an MS performs SFC with Cells to obtain a dedicated channel. If there is an idle dedicated channel in Cells, the new traditional call is accepted. Otherwise, the new traditional call is blocked, which is referred as "new traditional call blocking". To complete a traditional call, the MS performs SFD with Cells, and a dedicated channel is released. The details of SFC and SFD can be found. To join the MBS service, the MS executes PSJ with Cells and the MBSC to obtain a common channel. For a new MBS call arrival, the MBSC checks whether the data flow to Z for the MBS service exists. If the data flow does not exist, the MBSC negotiates with all cells in Z for bearer resources, and establishes the MBS data flow to all cells in Z. Then, the MBSC sets zone to enabled. All cells in Z turn on the same common channel to activate the MBS zone technology. Afterward, the MS can receive the MBS content from the common channel of Cells. To disjoin the MBS service, the MS executes PSL with Cells and the MBSC. When an MBS call is completed, the MBSC determines whether to deactivate the MBS zone technology in Z. If there is no MBS calls in Z, the MBSC informs all cells in Z to turn off the same common channel to deactivate the MBS zone technology. The MBSC terminates the MBS data flow to Z, and sets zone to disabled. During a traditional call or an MBS call, an MS may move from the old cell Cello to the new cell Celln, which is referred as "handoff". The MS performs the MAC Layer Handoff procedure to synchronize the downlink of Celln. For a handoff traditional call, the MS performs SFC with Celln to re-establish the traditional call in Celln. If an idle dedicated channel in Celln is available, the handoff traditional call request is accepted. Otherwise, the handoff traditional call is forced to terminate in Celln. Suppose that Cello and Celln belong to Zo and Zn, respectively.

For a handoff MBS call, the MS checks whether Zn is equal to ZOo If Zn i=- Zo, the MS exercises the interMBS zone handoff, which is executed as follows: Through Celln, the MS notifies the MBSC that it has left ZOo If there is no MBS call in Zo, the MBSC deactivates the MBS zone technology in ZOo Afterward, the MS exercises PSJ with the MBSC to resume receiving the MBS content in Celln. Otherwise (i.e., Zn = Zo), the same common channel is used to multicast the MBS content, and the MS exercises the intraMBS zone handoff. The MS continues to receive the MBS content in C elln using the same common channel. In scheme Basic, a common channel with the MBS zone technology is always reserved to serve MBS calls. A new MBS call request to the BS or a handoff MBS call request (i.e., an ongoing MBS call moves from the old BS to the new BS belonging to the same MBS zone) can always be accepted. However, the reservation of a common channel in all cells in an MBS zone implies that there are at most C; = Ci - dz - 1 dedicated channels in Celli to serve the new or handoff traditional calls even when there is no MBS call in Celli. Obviously, the radio resource is not fully utilized in the MBS zone technology. To summarize, scheme Basic does not take the following two issues into consideration to enable the MBS zone technology:

I) The channel pool status (to enable the MBS zone technology, e.g., the number of served MBS calls);
II) The common channel or the dedicated channel (to serve the MBS calls). There are seldom previous works touching on these issues.

II. DYNAMIC CHANNEL ALLOCATION

In this section, we propose two Dynamic Channel Allocation schemes, DCA and EDCA, for the MBS network. In DCA, the MBSC attempts to activate the MBS zone technology if the number of MBS calls in all cells (belonging to the same MBS zone) is equal or larger than a pre-defined B. When the MBS zone technology is disabled, DCA turns on a common channel to serve the MBS calls if the number of MBS calls in the cell is larger than de. The EDCA enhances

DCA by putting the behavior of the traditional call into consideration. When a traditional call arrives in a cell where there is no free dedicated channel, EDCA attempts to have more dedicated channels by activating or deactivating the MBS zone technology.

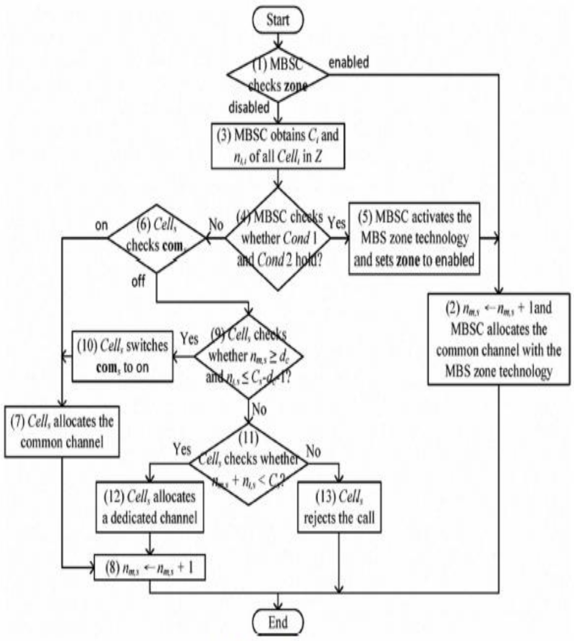
A. Scheme of DCA

The DCA handles a new or handoff traditional call request in the same way of Basic. In DCA, we modify the PSJ and PSL procedures in Basic as follows:

Figure 3 (a) depicts the flowchart for PSJ_D.

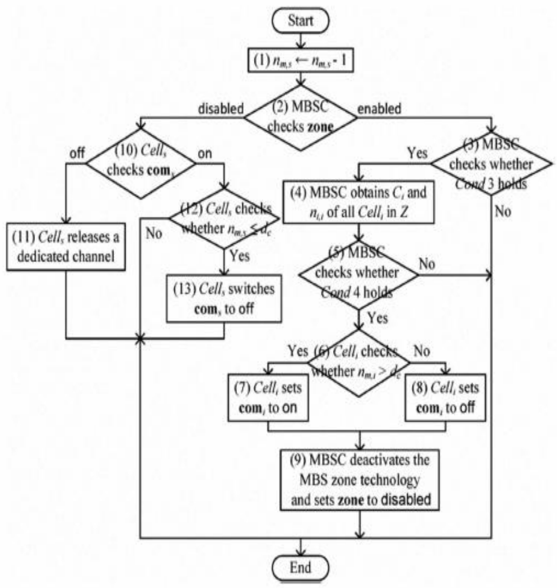
For a new MSB call arraival.

For a handoff traditional call (moving from Cello to Celln), the MS performs the MAC Layer Handoff procedure to synchronize the downlink of Celln. Cello sets nt,o +--nt,o-l, and the MS performs the SFC_E procedure in Celln.



(a) Flowchart of PSJ_D

Figure 3 (b) depicts the flowchart of PSL_D. When an MBS call is completed,



(b) Flowchart of PSL_D

Fig. 3. Flowcharts of PSJ_D and PSL_D

B. Scheme of EDCA

In DCA, the activation of the common channel with/withoutthe MBS zone technology is determined after the MBSC checks the channel status of all cells in an MBS zone, which introduces signaling message exchange overhead. Similar to DCA, not only for the activation of the common channel but also for the traditional call requests, EDCA introduces higher signaling message exchange overhead than DCA does. DCA and EDCA may have better system capacity, but more signaling overhead. Consequently, in the remaining sections, we propose analytical models and simulation models for the three schemes, investigate the performance for the three schemes, and provide the guidance for the network operators to operate which scheme under different system traffic and MS mobility behavior.

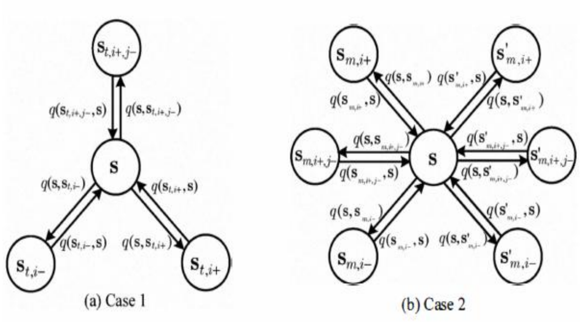
III. ANALYTICAL MODELS FOR DCA

Proposed analytical models to investigate the performance of schemes Basic, DCA and EDCA, and validate these models by simulation experiments. The output measures of these models are the new call blocking probability Pbt,i for the traditional calls (Pb=,i for the MBS calls) and the handoff call force-termination probability Pi . for the traditional calls (Pi""i for the MBS calls) at Ce t ili' In the tradition call (or the MBS call) channel assignment of the three schemes, the handoff calls and new calls are not distinguishable.

Thus at Celli, Pbt,i = Pit,i and Pb=,i = Pi""i'

The Iterative Algorithm for DCA:
Step 1. Select an initial value for Aht,i' Ah""i' 7r sand 7r St,H' where 1 < i < K, and S = (0, ... ,0).
Step 2. A'h:di +- Aht,i' and A'h<- i +- Ah=,i'
Step 3. Compute Aht,i and Ah>,i by using (10) and (1 1), respectively.
Step 4. If IAht,i - A'h:di I > tlAht,i or IAh""i - A'h> i I > tlAh""i' then go to '
Step 2. Otherwise, go to Step 5.

Step 5. The values for Aht,i and Ah""i converge. Compute Pbt,i and Pb""i by using (12) and (13). Scheme Basic has the same channel allocation behavior as DCA except that in Basic, the MBS zone technology is always enabled. Therefore, the analytical model for Basic is a special case for that of DCA by setting () = 0 and initially setting z = 1.



(a) Case 1

(b) Case 2

Fig. 4. The state transition diagram for DCA. (a) Case 1. (b) Case 2.

Figure 4 illustrates the transition diagram of this Markov process for DCA, where q(a, b) denotes the state transition rate from state a to state b.

IV. PERFORMANCE EVALUATION

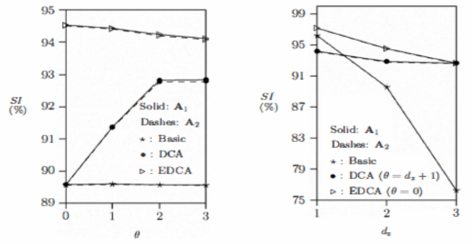
Investigate the performance of schemes Basic, DCA, and EDCA in terms of the Satisfaction Indication (denoted as S 1) [5][10] to reflect the MS' satisfaction about the MBS network. Let Pc, (Pc=) be the probability that a traditional (an MBS) call is completed, Pi, (Pi=) be the probability that a traditional (an MBS) call is connected but is eventually forced-terminated, tc, (tc=) be the effective expected call holding time for a traditional (an MBS) complete call, Tit (Ti=) be the effective expected call holding time for a traditional (an MBS) incomplete call, and E[tc,] = 1/ fJt (E[tc=l = 1/ fJm) be the expected non-interrupted traditional (MBS) call holding time. Then S1 can be expressed as

$$SI=\left[\frac{\sum_{j=1}^{K}\lambda_{o_{t,j}}}{\sum_{j=1}^{K}(\lambda_{o_{t,j}}+\lambda_{o_{m,j}})}\right]\left(\frac{P_{i_t}T_{i_t}+P_{c_t}t_{c_t}}{E[t_{c_t}]}\right) + \left[\frac{\sum_{j=1}^{K}\lambda_{o_{m,j}}}{\sum_{j=1}^{K}(\lambda_{o_{t,j}}+\lambda_{o_{m,j}})}\right]\left(\frac{P_{i_m}T_{i_m}+P_{c_m}t_{c_m}}{E[t_{c_m}]}\right).$$

Note that 0 < S1 < 1 and a larger S1 implies a higher MS satisfaction.

In the simulation experiment, we set K = 3 for an MBSzone Z (i.e., Z = {CellI, Cell2, Cell3}), and consider two MS mobility patterns Al and A2:

$$\mathbf{A}_1 = \begin{pmatrix} 0 & 1/3 & 1/3 & 1/3 \\ 1/3 & 0 & 1/3 & 1/3 \\ 1/3 & 1/3 & 0 & 1/3 \\ 1/3 & 1/3 & 1/3 & 0 \end{pmatrix}_{4\times 4},$$



(a) (b)

Fig. 6. (a) Effects of θ ($K = 3$, $C_i = 6$, $d_c = 3$, $d_z = 2$, $\lambda_{o_{t,i}} = 1.5\mu_t$, $\lambda_{o_{m,i}} = 0.5\mu_t$, $\eta_i = 0.05\mu_t$, $\mu_m = 0.25\mu_t$); (b) Effects of d_z ($K = 3$, $C_i = 6$, $d_c = 3$, $\lambda_{o_{t,i}} = 1.5\mu_t$, $\lambda_{o_{m,i}} = 0.5\mu_t$, $\eta_i = 0.05\mu_t$, $\mu_m = 0.25\mu_t$)

$$\mathbf{A}_2 = \begin{pmatrix} 0 & 2/3 & 1/6 & 1/6 \\ 1/3 & 0 & 1/3 & 1/3 \\ 1/6 & 2/3 & 0 & 1/6 \\ 1/6 & 2/3 & 1/6 & 0 \end{pmatrix}_{4\times 4}.$$

In AI, an MS has equal probability (i.e., 1/3) to move to the neighboring cells in Z or move out of Z. Each cell has almost the same average number of residing MSs. In A2, an MS in Cell2 (Celb) has probability 2/3 to move to CellI, and probability 1/6 to move to Cell3 (Cell2) or move out of Z. An MS in Celh has equal probability (i.e., 1/3) to move to the neighboring cells in Z or move out of Z. The average number of residing MSs in Celh is higher than that in Ce1l2 or Celb.

In our study, the input parameters AO"i' AO=,i' fJm and 'T/i are normalized by fJt. For example, if the expected traditional call holding time is 1/ fJt = 45 seconds, then AO"i = 0.5fJt means the expected traditional call inter-arrival time is 90 seconds.

V. CONCLUSION AND FUTURE WORK

DCA and EDCA are more flexible channel allocation for MBS, which improve the Safe performance for users. However, more signaling overheads are caused by DCA and EDCA. Therefore, we proposed analytical and simulation models to study the Sf performance for Basic, DCA, and EDCA. Our study provides the following guidance for MBS network operators when to use Basic, DCA, or EDCA:

- In the DCA, When the macro diversity functions well (i.e., dz is smail), Basic is the good choice since the Sf performance for the three schemes are almost the same. On the other hand, when dz is large, EDCA is the better choice than DCA.
- As the number of MBS calls in a cell is larger (i.e., higher AO""i' lower 'T/i, or lower f.Lm), EDCA is the better choice than DCA.
- The performance enhancement of EDCA over DCA decreases as AO\,i increases. Therefore, when traditional call arrival rate AO\,i is higher enough, DCA is suggested.

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