High Altitude Platforms: Radio Resource Management Policy for MBMS Applications

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Abstract. In this work we are interested in investigating how the High Altitude Platform (HAP) can efficiently support Multimedia Broadcast/Multicast Service (MBMS) in a scenarios wherein the terrestrial network is not available. To this aim, we propose to implement an efficient policy of Radio Resources Management (RRM) into the HAP Radio Network Controller (H-RNC). The proposed technique allows to improve the overall system capacity by selecting the most efficient multicast transport channel in terms of power consumption and by defining the switching thresholds between point-to-point and point-to-multipoint connections.

Keywords: HAP, Radio Resource Management, MBMS, Multicast transmission.

1 Introduction

The widespread diffusion of new services, such as for example video conferencing or streaming, into the cellular environment has originated the need for a point-to-multipoint (PtM) communication modality supporting information exchange among one sender and several mobile receivers. Therefore, the third generation partnership project (3GPP) introduced a new protocol, called Multimedia Broadcast/Multicast Service (MBMS), to the purpose of providing *groups oriented* services. Notwithstanding, a terrestrial-only MBMS segment may still be inadequate to environments showing high exacting communication requirements. It is the case of so called disadvantaged areas; for instance, either rural areas or areas involved in unpredictable catastrophic incidents. Advantages deriving from the MBMS extension to space-terrestrial integrated platforms, known as Satellite-MBMS (S-MBMS) [1], [2] are manifest; they are mainly related to: wider coverage area capability, reduction of terrestrial segment overloading, overall cost reduction as a consequence of multicast service delivery to more users within the same coverage area, etc. In spite of the highlighted advantages, the use of satellites implies severe limitations, mainly due to well known features, such as: heterogeneity of the channel quality, long propagation delays (in case of geostationary ,GEO, satellites) and high complexity (in case of low-Earth orbit, LEO, satellites).

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High Altitude Platforms (HAPs) are a valid space segment alternative to satellites in supporting MBMS services and applications, particularly when disadvantages areas are taken into account. HAPs are stratospheric platforms, usually located at an altitude of 17-22 km, which may be effectively regarded as a very low satellite. Some of the advantages have been clearly highlighted in [3] and can be summarized in the following: rapid deployment, broadband capability, large area coverage, very large system capacity, low propagation delay. Moreover, HAPs could be either utilized as base stations in the sky (*standalone* case) or as an overlapping coverage (*integrated system* case). In this work we consider the former case, because we are interested to investigate how the HAP can efficiently support the MBMS services in a scenario wherein the terrestrial network is not available.

To this aim, we foresee to implement in the HAP Radio Network Controller (RNC) an efficient policy of Radio Resources Management (RRM). It has to reduce as much as possible the power consumed by a HAP base station, for a given *multicast group*. The saved power will allow to increase the overall system capacity while reducing the impact of multicast services on the pre-existing unicast traffic; both traffic typologies, in fact, share the same radio resource. The limitation in the power that the transmitter can use to deliver multicast traffic, pushes towards the wise selection of the most efficient transport channel in terms of power consumption. MBMS services can utilize over the radio interface *Common* (Forward Access Channel, FACH), *Dedicated* (Dedicated Channel, DCH) and *Shared* transport channel (High Speed Downlink Shared Channel, HS-DSCH). Power saving is related to the number of users receiving MBMS data; in fact, if such number increases, then one needs a higher amount of DCHs; this reducing the resources made available to unicast traffic. It is, therefore, important to decide the maximum number of multicast users using the DCHs that allows a power saving. Such a number represents a very useful threshold to switch from dedicated channel to either common or shared ones (these being channel, which instead allow to provide multicast services utilizing a fixed amount of power, regardless of multicast users number). The sought power threshold depends on *(i)* the distance from the centre of the area covered by the HAP; *(ii)* the application bit rate.

The state of the art in term of MBMS radio resource optimization witnesses to the great amount of work that has been conducted on *Switching Thresholds* investigations only considering the UMTS terrestrial network [4], [5], [6]. The present paper contributes to the advance of the state-of-the-art in that our RRM policy gives a novel contribution to the definition of the *Switching Thresholds* from *Dedicated* to *Common* channels, when considering MBMS transmissions from HAPs systems in a standalone case.

The paper is structured as follows. Section 2 provides a brief overview of the integration of HAPs into the MBMS architecture. Section 3 describes the transport channels features considered in our research work, for multicast transmissions from the HAPs. Main results of a simulation campaign aiming at defining the RRM policy are the focus of Section 4. Conclusive remarks are given in Section 5.

2 MBMS/HAP Architecture

A possible modality for including HAPs into a MBMS architecture to provide multicast/broadcast service delivery is shown in Figure 1. It implies the addition of an

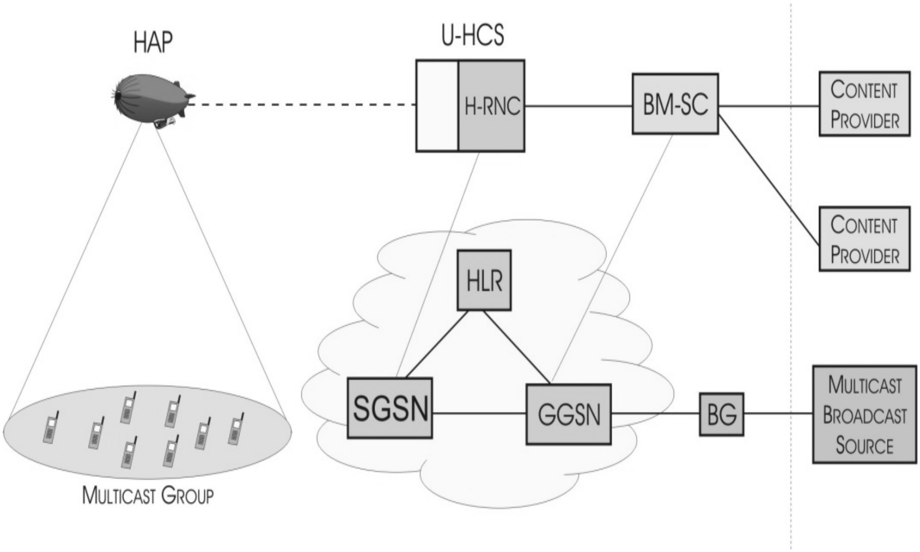

Fig. 1. MBMS/HAPs Architecture

UMTS-HAP Control System (U-HCS) to the MBMS architecture, with functionality of Radio Network Controller (H-RNC).

HAP carries a UMTS payload, at an altitude of 22 km above the service area. Therefore, Figure 1 highlights the node of the UMTS terrestrial network used in a HAP system. In particular, we can notice the presence of the following elements: *SGSN (Serving GPRS Support Node)* that carries out user individual service control functions and gathers together all individual users of the same MBMS service into a single *MBMS group*; *GGSN (Gateway GPRS Support Node)* that terminates the MBMS GTP tunnels from the SGSN and links these tunnels with the MBMS data source via IP multicast; *BM-SC (Broadcast-Multicast Service Center)* that is the new element introduced into such an architecture to provide MBMS data.

Even if the proposed MBMS/HAP architecture seems to show a behaviour very close to the MBMS/UMTS terrestrial network [7] one, notwithstanding several important differences (reported in Table 1) between *terrestrial* and *space* segments needs to be taken into account to determine the right *Switching Thresholds*.

Table 1. MBMS/UMTS terrestrial network vs MBMS/HAP system

Features	Terrestrial Wireless	HAP
Breadth of geographical coverage	A few kilometres per base station	Hundreds of kilometres per platform (up to 200km)
Cell diameter	0.1 – 1 km	1 – 10 km
Shadowing from terrain	Causes gaps in coverage; requires additional equipment	Problem only at low elevation angles
Antenna Gain	Constant	Variable
Path Loss	Okumura Hata	Free Space

The most evident difference is represented by the propagation environment. Indeed, HAPs enjoy more favorable *Path Loss* characteristics compared to wireless terrestrial links, since in the *Free Space* case the received power decays as a function of the transmitter-receiver distance raised to a power of 2. While, in wireless terrestrial systems, where the *Okumura Hata* model is taken into account, the received power decays as a function of the transmitter-receiver distance raised to a power of 4 [6].

3 MBMS/HAP Transport Channels

As mentioned in the introduction, the HAP system can use the dedicated transport channel DCH, the common transport channel FACH or the shared transport channel HS-DSCH for MBMS applications. As our novel contribution aims at defining the *Switching Thresholds* from *Dedicated* to *Common* channels, we provide a brief overview of the modality to assign the transmission power to DCHs and FACH.

The total downlink transmission power allocated to the DCHs varies depending on: *(i)* the number of multicast users; *(ii)* the position of users with respect to the centre of the area covered by theHAP, (for instance, users close to the centre need a lower amount of power than users at cell border); *(iii)* the application bit rate. Equation (1) defines the total transmission power assigned to a number of DCHs equal to "*i*" scattered in a given cell [8].

$$P_{T,i} = (C/I)_i \frac{\sum_{j=1}^{N_c} G(\theta_j, d_j) P_T + (1-\alpha) P_{Tot(i-1)} G(\theta_i, d_i) + P_p G(\theta_i, d_i) + N_d}{G(\theta_i, d_i)} \tag{1}$$

Where N_c is the number of interfering neighboring cells, P_T is the interference from such cells, α is the orthogonality factor that can be zero in the case of perfect orthogonality, $P_{Tot(i-1)}$ is the power allocated to a number of users equal to $i-1$, P_p is the power devoted to common control channels, N_d is the Additive Gaussian White Noise (AGWN). While $G(\theta_j, d_j)$ is the link gain and C/I is the Carrier-to-Interference ratio, calculated by Equation 2 and 3 respectively.

$$G(\theta_i, d_i)_{dB} = g(\theta_i)_{dB} - L_p(d_i)_{dB} \tag{2}$$

$$(C/I)_{dB} = (E_b/N_0)_{dB} - (G_p)_{dB} \tag{3}$$

Where θ_i is the angle representing the boresight direction [9], $g(\theta_i)$ is the *Antenna Gain* calculated in the boresight direction, $L_p(d_i)$ is the attenuation value caused by the *Path Loss* for the user at a distance equal to d_i from the centre of the area covered by the HAP. While E_b/N_0 is the Energy per Bit-to-Spectral Noise Density and G_p is the Processing Gain.

A FACH channel transmits at a fixed power level, since fast power control is not supported in this kind of channel. It is a PtM channel and must be received by all UEs throughout the cell covered by the HAP, regardless of the considered *Path Loss* and

Antenna Gain. Therefore, the fixed power has to be high enough to guarantee the services in the whole coverage area [10]. The bit rate of the MBMS services and the needed coverage area of the cell affect the allocated power for the FACH channel. The delivery of high data rate MBMS services over FACH is not always feasible, since excessive downlink transmission power would be required. High bit rates can only be offered to users located very close to the centre of the area covered by the HAP.

4 Obtained Results

An exhaustive simulation campaign has been conducted to define a RRM policy aimed to select the advisable *Switching Thresholds* from *Dedicated* to *Common* channels, considering MBMS transmissions from HAPs systems in a *standalone* case. Table 2 summarizes the main considered assumptions [11], [12]. Parameters not listed are varying during the different campaigns.

Table 2. Simulation Campaign Assumptions

Parameter	Value
HAP High	22 Km
Cell Radius	2.6 Km
Cell Layout	Hexagonal grid
Number of Neighboring Cells	7
Maximum BS Tx Power	40 W
Other BS Tx Power	10 W
Common Channel Power	2 W
Path Loss	Free Space
Multipath Channel	Vehicular A (3Km/h)
Orthogonality Factor	0,5
BLER Target	1 %
Gmax	32,3 dBi
Thermal Noise	-100 dBm
Application Bit Rate	64, 128, 256 Kbps

In Figure 2 the *Switching Thresholds* are defined when 64 kbps is the considered bit rate. Moreover, to highlight how the user mobility and position can affect the proposed RRM algorithm, three situations have been investigated in which multicast users are scattered respectively within 50%, 75% and 95% of cell coverage size. From Figure 2, it clearly emerges that the DCHs behavior weakly depends on the users position, while the FACH assigned power strictly depend on the covered area and, hence, on the position of the farter multicast user (5.6 W, 8.8 W and 15.2 W for 50%, 75% and 95% of cell coverage size respectively).

The difference between DCHs and FACH behavior is due to a different modality in assigning the channel transmission power, as explained in Section 3. Hence, for 64 kbps, in the worst situation, the maximum power needed to provide MBMS services in the area is equal to 15,2 W. The remaining 24,8 W could be used to serve unicast applications.

According to our RRM policy, the HAP RNC continuously keeps track of both position and number of multicast users that utilize DCH channels. In so doing, the RNC can decide the power to assign to the FACH and, as a consequence, the *Switching Thresholds*. In particular, when multicast users are scattered within 50%, 75% and 95% of area covered by the HAP, the *Switching Thresholds* from DCHs to FACH are equal to 34, 44 and 55 respectively.

Similar considerations can be made for 128 and 256 kbps applications, illustrated in Figure 3 and 4 respectively. As shown in the figures, FACH channel requires a higher power with respect to the previous case. In particular, when 128 kbps is the application bit rate, an amount of power equal to 31,6 W is needed when 95% is the cell coverage.

For this reasons, for 128 kbps, our proposed RRM policy allows to utilize FACH channel up to 75% of cell coverage and the remaining multicast users will be served by DCH channels. This choice enables to save a sufficient amount of power (about 50%) for unicast users and allows to obtain interesting results in term of Grade of Services for both unicast and multicast traffic. Hence, when multicast users are scattered within 50% and 75% of area covered by the HAP and 128 kbps is the service bit rate, then the *Switching Thresholds* from DCHs to FACH are equal to 28 and 32 users respectively.

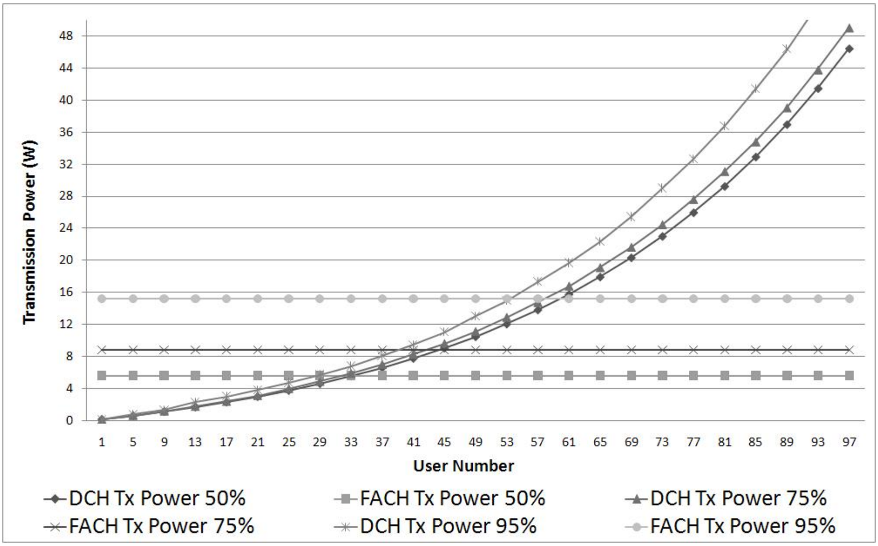

Fig. 2. Tx power vs. Cell Coverage for applications with a bit rate of 64 kbps

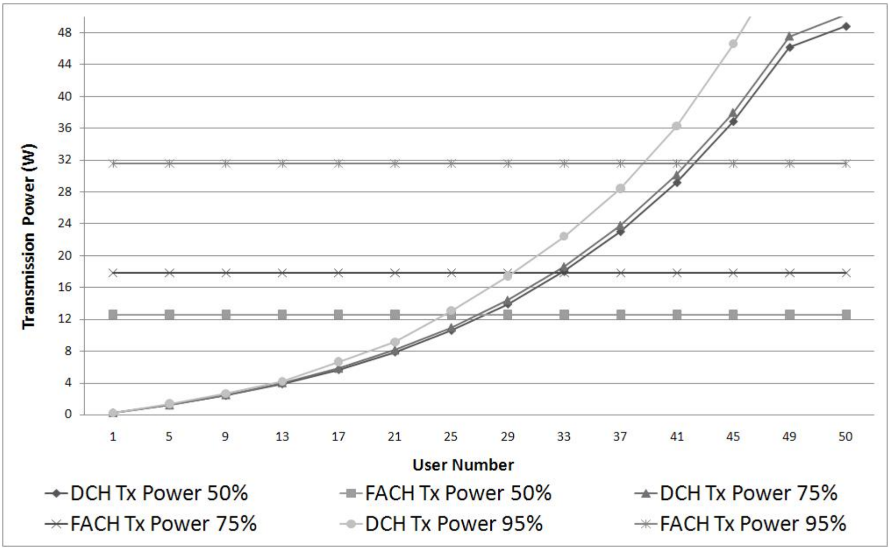

Fig. 3. Tx power vs. Cell Coverage for applications with a bit rate of 128 kbps

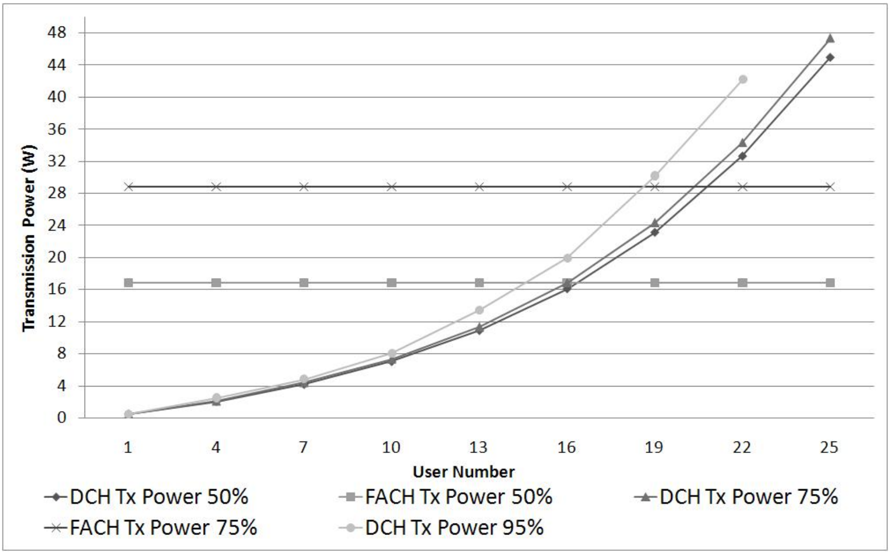

Fig. 4. Tx power vs. Cell Coverage for applications with a bit rate of 256 kbps

In case of 256 kbps services the FACH transmission power is not defined for a cell coverage equal to 95%, because the required power would be greater than the overall HAP transmission power. Hence, when the application bit rate is equal to 256 kbps, the *Switching Thresholds* are defined only for 50% and 75% cell coverage and are equal to 16 and 20 users respectively.

Moreover, when the FACH is active to cover a given area, some of the served MBMS user could leave the *multicast group*. In this case, the RRM policy allows the system to check if the exploitation of DCH channels becomes again more efficient, in term of power consumption, than the use of FACH. Therefore, the switching from FACH to DCHs channels is performed, this leaving further resource available to unicast traffic.

5 Conclusion

In providing MBMS services the choice of the most efficient transport channel is a key aspect, since a wrong transport channel selection could adversely affect the overall capacity of the system. In this paper we defined a RRM policy aiming at identifying the best *Switching Thresholds* among DCH and FACH channels, by taking into account the radio channel conditions, the cell coverage radius, and two sample MBMS application bit rates.

Obtained results demonstrate that a smart selection of transport channels coupled to the use of the proposed *RRM* policy, leads to an efficient management of MBMS services in a HAP standalone scenario.

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