Abstract—— In this article we propose strategies for optimization of vertical handover among broadcast networks. The specific technologies of DVB-H and UMTS/MBMS are taken into account for the modelling of technological parameters including energy consumption and frame loss. Energy consumption is important in a mobile context in order to maximize the possible service duration while frame loss must be considered in order to provide services with an acceptable quality of experience. The proposed strategies are based on two different functions: a ratio between the energy consumption and the frame loss along and a linear objective function. The two function are compared with functions based on only one parameter and against the theoretic frame loss and energy consumption. The paper gives numerical results obtained through simulations in different mobility conditions in order to assess the performance of the proposed functions in terms of frame loss and energy consumption as well as in frequency of vertical handovers.

I. INTRODUCTION

Broadcast network are growing in interest due to their low cost for the network provider and for their capacity to provide multimedia services to an high number of users simultaneously with high quality of services.

Two types of broadcast network are becoming widely used: UMTS/MBMS (Multimedia Broadcast Multicast Service) and Digital Television Broadcast (DVB).

The former, UMTS/MBMS [1] (Multimedia Broadcast/Multicast Service), is based on the UMTS cellular network. MBMS provides two possible operational modes, i.e. broadcast and multicast, where the data are delivered from the base station to all the users or towards a group.

The latter is more oriented to the digital television, i.e. it is based on the DVB [2.] (Digital Video Broadcasting). In the present paper the extension for the handheld devices (DVB-H) [3.] is considered. DVB-H (Digital Video Broadcast-Handheld) is a new standard released by ETSI to allow mobile devices. This standards is based on the DVB terrestrial standard (DVB-T [4.]). DVB-H works with the frequency set that is used by the analogue television, i.e. 470-830 MHz for the UHF set and 174-230 MHz for the VHF set with a channel that can be from 5 to 7 MHz. DVB-H introduces some improvements, the one that is relevant for this article is the MPE-FEC (Multi Protocol Encapsulation-Forward Error Correction) that adds error resilience.

Scope of this paper is to investigate into the mechanism for vertical handover between broadcast network taking into account the technological peculiarities of DVB-H and UMTS/MBMS. Strategy based on functions are defined in order to evaluate the best network where the service is taken.

The paper is organized as follows: section 2 describes the state of the art in vertical handover especially targeting the broadcast network and gives the technological details and their formalization of DVB-H and UMTS/MBMS technologies, section 3 gives the details of the cost function used with special attentions for the formalization of the involved parameters, the section 4 shows the simulation results for each presented cost function while the remaining of the paper gives the conclusions.

II. STATE-OF-THE-ART

A. Vertical Handover

The Always Best Connected paradigm (ABC), described in [5.], is a novel paradigm that permits the user to receive the service using the best available network technology. In order to support ABC resources management procedures handling heterogeneous network must be defined. The procedure that is considered in this article is the vertical handover, i.e. handover between different technologies. Vertical handover must assure that the best network, among the currently available, is chosen guaranteeing at the same time quality of service and, possibly, service continuity.

Recent years have seen a lot of research in vertical handover at standardization and academic level:

- **Standardization**, the main bodies dealing with vertical handover is the IEEE802.21 working group that is currently defining standards for vertical handover [6.] between different technologies but such standard does not take into account or investigate too little about broadcast network

- **Academic research**, an overview of vertical handover decision strategies is presented in [7.]. Among the possible strategies there are function-based strategies, where a single decision cost function is developed in order to measure the cost of receiving services on a network. Such approaches are an evolution of the concept of policy enabler handover decision [8.]. More recent approaches are
based on an adaptive schema or a trade-off between user satisfaction and network efficiency and multiple attribute decision strategies [7], in details there are four types of such approach: single additive weighting, techniques for order preference by similarity to ideal solution, analytic hierarchy process and grey relational analysis.

In vertical handover, but also in horizontal handover but at less extent, the strategies must take into account: ping pong effect [9.], i.e. handover between two networks with high frequency, power consumption, i.e. mobile terminals must take into account energy consumption in providing services to the user as well as for the handover execution and packet loss, i.e. quality of service must be maximized choosing among the available network.

Both in standardization and at academic level there is a lack of analytic strategies for handover between broadcast networks. In the rest of this paper we formalize strategies based on energy consumption and frame loss for the DVB-H and UMTS/MBMS technologies that can be used for vertical handover.

B. DVB-H and UMTS/MBMS technological details

In this paragraph we illustrate the technological details that are considered concerning the modelling of DVB-H and UMTS/MBMS for energy consumption and frame losses. Concerning energy consumption we have:

- UMTS/MBMS, as the ordinary UMTS does can uses Discontinuous Reception Modes (DRX) [1] but in such case all the mobile terminals must support it and the internal state machine must be synchronized among all the mobile terminals, if it is not so some terminals consume more, i.e. they have a shortest idle time, while others lose important packets, i.e. they have a longer idle time. In the rest of this paper we base our approach on the following papers [10] that gives detailed analytic formula for the calculus of power saving ratio and energy consumption. In fact we use such analytic formula for the theoretical UMTS/MBMS power saving but with the best possible timer value and validate them in a possible vertical handover environment, in fact we also consider the terminal consuming in off time with the values provided in [11].

- DVB-H, in order to increase battery life DVB-H uses time slicing. An analytic formula is given in the standard [12], we refer to it in order to consider the power consumption values. The off-time in time slicing can be used by the terminal in order to scan for a nearest broadcasting cell, we do not take into account such power consumption because we are focused only on vertical handover and because of the DVB-H cell size. In fact DVB-H cell size can be very great and not comparable to the size of a UMTS cell, in such case the horizontal handover between DVB-H cells is done not too often and such power consumption can be neglected.

Concerning frame loss we have:

- UMTS/MBMS, the standard used for the MBMS error correction code is Raptor Codes at Application Level [11]. In the rest of this paper we consider 2 byte for a Source Block Number (SBN) and 1 byte for Encoding Symbol ID (ESI).

- DVB-H, as already stated it introduces MPE-FEC to improve C/N performance and Doppler performance in mobile channels and the tolerance to impulse interference. The theoretical frame loss formula that is used in the rest of this paper is the one formalized in [13].

III. VERTICAL HANDOVER STRATEGIES FOR OPTIMIZATION IN BROADCAST NETWORK

In this section we define strategies in order to choose an effective vertical handover strategy for broadcast networks taking into account energy consumption and frame loss.

The following four strategies are considered and used to optimize the vertical handover decision:

- **Energy Consumption (SE)** - The User Equipment (UE) examines the consumed energy every 100 ms and chooses the lowest average consumption of energy for both technologies (DVB-H, UMTS).

- **Frame Loss (SF)** - The UE examine the frame loss every 100 ms and chooses the lowest frame loss for both technologies. For the frame loss calculations IP packets 512 bytes long are assumed in order to avoid packet fragmentation.

- **Ratio (SR)** - The UE examines the ratio function \(R\) for each network every 100 ms and chooses the lowest ratio. R function is defined as:

\[
R_{\text{DVB-H}} = \frac{E_{\text{DVB-H}}}{1 - F_{\text{DVB-H}}}
\]

\[
R_{\text{UMTS}} = \frac{E_{\text{UMTS}}}{1 - F_{\text{UMTS}}}
\]

where \(F_{\text{UMTS}}\) and \(F_{\text{DVB-H}}\) represent the frame loss of UMTS and DVB-H respectively. \(E_{\text{UMTS}}\) and \(E_{\text{DVB-H}}\) represent the consumption of energy of UMTS and DVB-H respectively. This function represent the energy consumed weighed compared to frame loss.
The ratio function dimensionally is an energy because the frame loss is a percentage, i.e. a dimension less quantity.

- **Cost (SC)** - The UE examines the cost function every 100 ms and chooses the lowest cost function (C) for both technologies. C can be defined as:

\[
C_{\text{DVB-H}} = \alpha \cdot (1 - PS_{\text{DVB-H}}) + \beta \cdot F_{\text{DVB-H}}
\]

\[
C_{\text{UMTS}} = \alpha \cdot (1 - PS_{\text{UMTS}}) + \beta \cdot F_{\text{UMTS}}
\]

where \(PS_{\text{UMTS}}\) and \(PS_{\text{DVB-H}}\) represent the power saving of UMTS and DVB-H respectively. \(F_{\text{UMTS}}\) and \(F_{\text{DVB-H}}\) represent the frame loss of UMTS and DVB-H respectively. \(\alpha\) and \(\beta\) are appropriate weights such that: \(\alpha + \beta = 1\).

An important parameter that must be considered when the different strategies are compared is the number of handover. Two different strategies, i.e. strategy \(i\) and strategy \(j\), can be compared according to the following comparison factor \(\Delta_{ij}\) (similar to the one defined in [8]):

\[
\Delta_{ij} = w_b \cdot \ln\left(\frac{N_i}{N_j}\right) + w_p \cdot \ln\left(\frac{P_i}{P_j}\right) + w_{FL} \cdot \ln\left(\frac{FL_i}{FL_j}\right)
\]

where: \(N_i, N_j\) are the number of handover of strategy \(i\) and \(j\), \(P_i, P_j\) are the power consumption of strategy \(i\) and \(j\), \(FL_i\) and \(FL_j\) are the mean frame loss of strategy \(i\) and \(j\).

### IV. Simulations

This section gives numerical simulation in order to validate the proposed cost functions evaluating them with different parameters.

Table I summarizes the general transmission parameters that are used for the scenario, Table II and Table III gives the specific parameter of the considered technologies, i.e. Table II gives the DVB-H transmission parameters while Table III gives the UMTS/MBMS discontinuous reception parameters.

The COST 231 Hata propagation model is select to estimate the coverage giving the presence in the considered scenario of 1 DVB-H cell and 3 UMTS/MBMS cells.

A single UE is supposed, no interference due to other user is considered due to the usage of broadcast networks. The UE moves at a speed of 1 m/s with a path duration of 2500 seconds.

The user movement is forced in order to create different scenarios where the different strategies are evaluated taking into account the possible different situations where an user can be, the considered scenarios are:

- **Scenario 1**: with very low frame loss and with good energy consumption;
- **Scenario 2**: with higher frame loss and with low energy consumption;
- **Scenario 3**: with low frame loss and by high energy consumption;
- **Scenario 4**: with high frame loss and by high energy consumption.

We analyze first the results of simulations in the scenario 1 (given in Figure 1), in such scenario it is possible to note that:

- DVB-H has a lower power consumption than UMTS according to the theoretical formula;
- SE strategy has lower energy consumption than the minimum between DVB-H and UMTS due to the fact that uses always the minimum between UMTS and DVB-H exploiting the UMTS when its energy consumption value is less than the one provided by;
- SE gives a mean frame loss that as an intermediate value between the UMTS and DVB-H, such value is due to the fact that UMTS is higher than the DVB-H in the considered scenario but the UE is connected for a part of the time to the UMTS and for the rest of the time to the DVB-H network.
- SF behavior is similar to the SE if the value of frame loss are considered instead of the value of energy consumed.
- SR strategy gives the same results of SE due to the fact that with low frame loss the ratio function is almost identical to the SE strategy;
- SC is insensible to alpha due to the fact that the frame loss contribution to the cost function is very small.

To understand the previous results it is important to note

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### TABLE I

<table>
<thead>
<tr>
<th>Parameter</th>
<th>UMTS</th>
<th>DVB-H</th>
</tr>
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<tbody>
<tr>
<td>Gr [dB]</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Gt [dB]</td>
<td>20</td>
<td>2</td>
</tr>
<tr>
<td>Fp [MHz]</td>
<td>2200</td>
<td>700</td>
</tr>
<tr>
<td>Pt [dBm]</td>
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<td>61</td>
</tr>
<tr>
<td>Prmin [dBm]</td>
<td>-100</td>
<td>-100</td>
</tr>
<tr>
<td>Noise [dBm]</td>
<td>-103</td>
<td>-105</td>
</tr>
<tr>
<td>Modulation</td>
<td>QPSK</td>
<td>QPSK</td>
</tr>
<tr>
<td>Error correction scheme</td>
<td>RTP FEC</td>
<td>MPE-FEC</td>
</tr>
<tr>
<td>IP packet length [byte]</td>
<td>512</td>
<td>512</td>
</tr>
<tr>
<td>Service Rate [Kb/s]</td>
<td>128</td>
<td>128</td>
</tr>
</tbody>
</table>

### TABLE II

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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</thead>
<tbody>
<tr>
<td>Burst Size [Mb]</td>
<td>1</td>
</tr>
<tr>
<td>Burst time [s]</td>
<td>0.4</td>
</tr>
<tr>
<td>Peak bit rate [Mb/s]</td>
<td>2.5</td>
</tr>
<tr>
<td>Cycle time [s]</td>
<td>7.81</td>
</tr>
<tr>
<td>MPE-FEC</td>
<td>½</td>
</tr>
<tr>
<td>Total off time [s]</td>
<td>7.41</td>
</tr>
</tbody>
</table>

### TABLE III

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Timer 1 [s]</td>
<td>20</td>
</tr>
<tr>
<td>Timer 2 [s]</td>
<td>20</td>
</tr>
</tbody>
</table>
that the value of variance of the considered values, e.g. power consumption or frame loss are high and comparable to the mean value, e.g. the distribution of frame loss can assume very different values in the considered scenarios. Fig. 2, 3, and 4 show the simulations results in the scenario 2, 3 and 4 respectively. It is possible to note that:

- SC is insensible to alpha in scenario 1 and 2 while if it is considered for scenario 3 for frame loss it can give different value of frame loss;
- Tuning the value of alpha permits to have performance more similar to the SE or to SF depending on the considered value.

As already stated it is important to compare the number of vertical handover; Fig. 5 gives the number of handover in different situation. It is possible to note that in the scenario 4 SF and SR gives the same number of handover and in order to choose between the different strategy is possible to use the comparison factor $\Delta_{ij}$ values of comparison factor for scenario 4 are given in Table IV with $w_n=w_p=0.4$ and $w_FL=0.2$.

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**Fig. 1.** Mean Power consumption and frame loss in Scenario 1

**Fig. 2.** Mean Power consumption and frame loss in Scenario 2

**Fig. 3.** Mean Power consumption and frame loss in Scenario 3

**Fig. 4.** Mean Power consumption and frame loss in Scenario 4
V. CONCLUSIONS

In this paper we have defined strategies for vertical handover applied for the first time to broadcast network. The novel UMTS/MBMS and DVB-H technologies are considered. With limited error probability and low energy consumption the best strategy is cost function strategy that permits to have a limited number of vertical handover. With an increased energy consumption and frame loss the ratio strategy permits to have a limited number of vertical handover.

REFERENCES

[1] 3GPP TS 22.146 V6.0.0 (2002-06) “Multimedia Broadcast/Multicast Service; Stage 1 (Release 6)”

<table>
<thead>
<tr>
<th>( \Delta_{ij} )</th>
<th>SE</th>
<th>SF</th>
<th>SR</th>
<th>SC1</th>
<th>SC2</th>
<th>SC3</th>
</tr>
</thead>
<tbody>
<tr>
<td>SE</td>
<td>0</td>
<td>-0.11</td>
<td>-0.14</td>
<td>0.021</td>
<td>0.14</td>
<td>-0.033</td>
</tr>
<tr>
<td>SF</td>
<td>-0.11</td>
<td>0</td>
<td>-0.028</td>
<td>0.13</td>
<td>0.028</td>
<td>-0.11</td>
</tr>
<tr>
<td>SR</td>
<td>-0.14</td>
<td>-0.028</td>
<td>0</td>
<td>-0.16</td>
<td>-0.29</td>
<td>-0.11</td>
</tr>
<tr>
<td>SC1</td>
<td>0.021</td>
<td>0.13</td>
<td>0.16</td>
<td>0</td>
<td>-0.12</td>
<td>0.05</td>
</tr>
<tr>
<td>SC2</td>
<td>0.14</td>
<td>0.26</td>
<td>0.29</td>
<td>0.12</td>
<td>0</td>
<td>0.17</td>
</tr>
<tr>
<td>SC3</td>
<td>-0.033</td>
<td>0.085</td>
<td>0.11</td>
<td>-0.05</td>
<td>-0.17</td>
<td>0</td>
</tr>
</tbody>
</table>

**Table IV**

Comparison Factor

**Fig. 5. Number of handover**