Incorporating Digital Repeaters into the Soft Handover Standard in Digital Video Broadcasting for Handhelds

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***Abstract* — Digital Video Broadcasting for Handhelds (DVB-H) is a standard for broadcasting IP data services to portable devices. Handover in unidirectional broadcast networks is a novel issue introduced by this technology. This paper proposes and analyses the Repeater Aided Soft Handover (RA_handover) algorithm for a DVB-H receiver with MIMO antennas and presents the benefits of implementing RA_handover compared with a handover process without repeaters. For network planning and optimisation purposes simulation models are developed to analyse the RA_handover approach. It is shown that RA_handover could greatly improve the quality of service and consume much less front-end battery power than a handover method without repeaters. In addition, the cost introduced by the algorithm is briefly estimated. In conclusion, curves are given that show the relationship between quality of service and consumed battery power, which provide further support for including RA_handover in the DVB-H soft handover standard. The paper provides valuable outcomes for service providers and standard policy makers.**

Index Terms —DVB-H, Handover, Repeaters

I. INTRODUCTION

With multimedia broadcast getting more attention from both broadcast and telecommunications operators (Cosmas *et al.* 2005) (Shchiglik *et al.* 2004), Digital Video Broadcasting for handhelds (DVB-H) (ETSI EN 302 304 V1.1.1, 2004), as a "one-to-many" broadcast system targeting PDAs, mobile phones, and laptop computers, is now being rolled-out.

DVB-T (Heidkamp *et al*. 2004) is not suitable for handheld devices partly because it would drain the batteries of a handheld terminal too fast for effective use (ETSI, EN 300 744, 2004). DVB-H is designed to overcome this limitation and offers a new outlet for content providers. DVB-H also provides much better service quality for mobile receivers than DVB-T.

The service contents in DVB-H networks will be delivered in the form of IP-packets using IPv6 protocol. Low power DVB-H transmitters offer the possibility of multi-frequency cellular DVB-H networks for the broadcast of localized services. With decreasing cell sizes, handover in DVB-H becomes a critical issue. Unfortunately, little work has been reported on handover in multi-frequency cellular DVB-H networks and few papers are available.

Repeaters provide an efficient way to increase the coverage of broadcasting networks (C.Trolet 2002). In broadcasting networks, the network operators usually first put high power transmitters at strategic points to quickly ensure an attractive coverage and then, in a second step, increase their coverage by placing low power repeaters in the dead spot or shadow areas, such as a tunnel, valley, or indoor area. A repeater is simply a device that receives an analogue or digital signal and regenerates the signal along the next leg of the medium. In DVB-H networks, there are two different kinds of repeaters. They are passive repeaters, which are also called gap-fillers, and active repeaters that are also called regenerative repeaters. A passive repeater receives and re-transmits a DVB-H signal without changing the signalling information bits. The signal is only boosted. An active repeater can demodulate the incoming signal, perform error recovery and then remodulate the bit stream. The output of the error recovery can even be connected to a local remultiplexer to enable insertion of local programs. This means that the entire signal is regenerated. The building blocks of the passive and active repeater configurations are shown in Fig.1. The repeaters used in the RA_handover approach are active repeaters. The foundation of the proposed RA_handover is active repeaters that can add extra signalling information to facilitate the handover decision-making. Passive repeaters only relay signals without adding extra signalling information, so it is not possible at the moment for RA_handover to be applied to passive repeaters. The utilization of passive repeaters for the modified RA_handover scheme needs to be studied further.

This paper proposes a novel approach called RA_handover to decide when soft handover should occur by incorporating intelligent digital repeaters into DVB-H networks. The DVB-H terminal considered in this paper is a DVB-H receiving capability only receiver with MIMO antennas (Telatar 1999) so that the receiver can receive and process signals from different transmitters and repeaters at the same time. In this handover approach an intelligent active repeater structure is proposed where each repeater can add repeater identification bits to the received DVB-H signal and retransmit it to the repeater covered area. Such an algorithm will greatly improve the quality of service of the received signals and reduce the receiver battery power consumption without considerably increasing the overall cost. The paper is organized as follows:

Section II presents the handover issues in DVB-H and the related work that has been done. Section III gives a detailed description of the proposed approach to deciding when soft handover should occur, namely, repeater aided soft handover or RA_handover. In Section IV, a simulation model is built and the performance analysis is done for the RA_handover approach. Section V concludes the paper.

II. SOFT HANDOVER IN DVB-H

DVB-H is intended to provide IP data services to mobile handheld devices. To provide diverse IP data services it is expected that a DVB-H cell will usually be smaller than a DVB-T cell and the multi-frequency cellular network structure will be a typical DVB-H network structure. Thus low power transmitters serving a dense multi-frequency cellular network, is expected to be the main network structure for DVB-H. Because roaming will be a quite common scenario in future DVB-H networks, handover becomes a critical issue.

Handover means the switching of a mobile signal from one channel or cell to another. This paper defines handover in DVB-H as a change of transport stream and frequency when the receiver moves from one DVB-H cell to another.

A. Soft handover in DVB-H Networks

Soft handover means that radio links are added and removed in such a way that the device always keeps at least one radio link to a base station (Yang *et al*. 2004). In DVB-H, this means that the received frequency and/or transport stream is changed without interruption of the on-going service. When the DVB-H terminal moves from one cell to another, it will try to synchronize with the new frequency of the target cell. This paper only considers the soft handover process in DVB-H. Wherever the word handover appears later in this paper, it will mean soft handover.

The handover process in cellular telecommunications networks always involves the participation of both the base stations and the handheld terminals. However, in the handover process of DVB-H networks the DVB-H transmitter cannot get a measurement report from a DVB-H receiver. Thus the handover process will be initialised and completed by the handheld device only. In the case of cellular telecommunications networks the handover is called active handover because of the involvement of the base station while handover in DVB-H networks is called passive handover because the transmitter is not involved in the handover process. Portable devices that can receive only DVB-H services will always use passive handover. However, portable devices that can receive DVB-H services and at the same time have cellular telecommunications capabilities can use both active handover and passive handover. So handover in DVB-H networks can also be divided into active handover and passive handover (DVB CBMS 1026 v1.0.0 Rev. 1/TM 3095 Rev.2, 2004). This is dependent on whether the network base stations and transmitters control the handover process or not. This paper will only consider passive soft handover where the receiver is a pure DVB-H receiver.

Handover in DVB-H consists of three stages: handover measurement, handover decision-making and handover execution (Yang *et al*. 2005). The handover measurement process provides the required measurement parameters such as RSSI (Received Signal Strength Indicator) or SNR (Signal Noise Ratio) to facilitate the handover-decision making process. Parameters such as RSSI or SNR are required for any handover decision-making algorithm. The handover decision-making stage is the stage where the handover decision is made according to predefined handover criteria and the obtained measurement parameters from both the handover measurement stage and the handover decision-making stage. The handover execution process performs the work of synchronizing to signals of the targeted handover cell after the targeted handover cell is chosen in the handover decision-making stage. The RA_handover algorithm proposed in this paper is focusing on the handover decision-making process.

B. *Time Slicing and Soft Handover*

Without time slicing soft handover in DVB-H would not be possible. Time slicing, which is shown in Fig.2, enables DVB-H to transmit data in burst mode. The receiver will only stay active for a fraction of the time and then switch to idle mode to save battery power. In the off burst duration, the receiver will measure the received signal strength from different cells and perform handover to the targeted cell. Since the receiver only makes handover measurement in the off burst time, the service will not be interrupted and so it is soft handover. An illustration of soft handover with time slicing mode in DVB-H is shown in Fig.3. Because the receiver can only receive the data passively without interactive communication with the transmitters, it has to make handover measurement during the off burst time. The more handover measurement is made, the more battery power will be consumed and the more quality of service decrease. So finding a way to reduce the handover measurement frequency becomes an important issue in the soft handover process of DVB-H.

C. *DVB-H Signalling For Soft Handover*

To implement handover in DVB-H, the receiver needs to receive signalling information from the network. There are two kinds of signalling information the DVB-H receiver can use. One is TPS (Transmission Parameter Signalling) signalling bits in the physical layer. The other is Service Information (SI) description data that forms part of the DVB-H transport streams (ETSI, EN 300 468, 2004). In this paper, new signalling information for TPS and SI in DVB-H soft handover is proposed which is described briefly as follows:

TPS is defined over 68 consecutive OFDM symbols referred to as one OFDM frame. Each OFDM symbol conveys one TPS bit so each TPS block contains 68 bits (ETSI, EN 300 744, 2004). The TPS bits needed for handover are derived from (ETSI, EN 300 744, 2004) and listed in TABLE I.

The Synchronization Word bits in TABLE I aid the receiver in synchronizing with the target transport stream and/or frequency. The Cell Identifier in TABLE I conveys unique cell identification information to the receiver. Bits numbered S_{51}-S_{53} in TABLE I were originally defined as Reserved For Future Use. All the other TPS bits are already used for certain functions in the DVB standard (ETSI, EN 300 744, 2004). Some of these Reserved For Future Use bits could be used to identify the RA_handover approach.

The SI data provide information on the DVB-H services carried by the different transport streams. Handover related information in SI is contained in the NIT (Network Information Table), which is derived from (ETSI, EN 300 744, 2004) and defined in TABLE II.

If the cell id information is announced in the TPS bits, the NIT (Network Information Table) in SI data will contain both a cell_frequency_link_descriptor and a cell_list_descriptor announcing all cells and subcells within the DVB-H network.

Using the TPS and SI information, the receiver can initialise and decide when handover should take place.

D. *Related Work on Soft Handover for DVB-H*

Handover in DVB-H networks is a new topic; little research work has been published. An instantaneous RSSI (Received Signal Strength Indication) value based handover scheme was proposed in (Väre and Puputti, 2004). This handover scheme is to the authors' knowledge the first for DVB-H published in the literature. This scheme uses the off burst time to measure the RSSI value. After comparing the current RSSI value with the RSSI values of adjacent cells, it hands over to the cell with the strongest RSSI value. Since the RSSI value can vary due to multipath interference or other environmental effects it may not give a true indication of communication performance or range and mistakenly measuring the RSSI value would result in unnecessarily consuming battery power because more off burst time would be used in handover measurement. It is possible in a worse case scenario that the RSSI value could end up being measured at least once every off burst period. Such an algorithm cannot avoid the *Ping Pong* effect. The *Ping Pong* effect is unnecessary frequent handover caused by signal fluctuation. This scheme cannot eliminate effectively the possibility of receiving "fake signals" either (Väre and Puputti, 2004). A fake signal is a signal that has a similar frequency to that of an adjacent cell but is from a far away cell. Constant measuring of the adjacent cells signal level without any handover prediction leads to unnecessary battery power consumption and receiving "fake signals" to degraded quality of service. To overcome these shortcomings a handover prediction algorithm has to be developed. Yang *et al*. (2004) proposed a handover decision-making approach based on post-processing of the measured SNR value to avoid the *Ping Pong* effect and to get rid of the received "fake signals". May (2005) proposed a technology called "phase shifting" to show how the off burst times can be used to perform soft handovers. Vare *et al*. (2004) proposed a Cell Description Table (CDT) based method to improve the performance of soft handover for a DVB-H terminal with GPS support. In a recent paper (Yang *et al*. 2005) different handover decision-making algorithms are presented and a novel hybrid handover decision-making algorithm is proposed. Research on the handover issue in DVB-H is currently being conducted in the IST INSTINCT project (http://www.ist-instinct.org).

In this paper, intelligent active repeaters are proposed to provide location information to mobile receivers. In this way, a receiver does not need to measure the handover parameters before it reaches the handover location reducing the *Ping Pong* effect and consequently battery power consumption. On the other hand, “fake signals” will be completely eliminated because all the repeaters provide their unique identification information to the receivers.

III. RA_HANDOVER ALGORITHM

Before going into the details of the proposed RA_handover algorithm, the novel active repeater structure proposed is presented. In this structure, shown in Fig.4, the TPS adapter adds unique repeater specific information to TPS bits in the transport stream.

In the RA_handover approach, the active repeaters are located in the cell border area. Each repeater-covered area is defined as one subcell. Unlike a passive repeater that simply amplifies and relays an incoming signal, an intelligent active repeater can demodulate the incoming transport stream, add handover scheme information and subcell id information to the TPS bits, and add subcell id information to the SI bits in the transport stream.

In the RA_handover approach, the DVB-H receivers are assumed to have MIMO (Multiple Input Multiple Output) antennas that can provide receiving and decoding capability from different transmitters and repeaters at the same time.

For the proposed RA_handover approach, intelligent active repeaters are put uniformly around the cell borders in a cellular DVB-H network. Actually there are already repeaters installed in the broadcast cell borders. A repeater-covered area defines a subcell and when a mobile device moves into such a subcell it receives the subcell’s unique repeater identification information from the repeater transmitted signals so the mobile device will know in which specific subcell it is located. When the device is in the repeater covered subcell, it will begin to measure the signal strength using the off burst time. Otherwise the receiver is idle mode in the off burst time. In this way, the measurement frequency in the off burst time is greatly reduced, saving battery power and improving quality of service. In addition, it also reduces the *Ping Pong* effect.

Fig. 5 illustrates the relationship between the different components and their operations in RA_handover.

Fig.5 can be taken as a general illustrative case of the RA_handover algorithm. The RA_handover algorithm's job is located in the handover decision-making stage of the DVB-H handover algorithm. In the handover measurement stage, the receiver receives the services from both the main transmitter and the repeater. Meanwhile, the signal RSSI or SNR is obtained constantly. In the handover decision-making stage, the signalling bits are obtained from the repeaters; this triggers the handover decision-making process. According to the RSSI or SNR value obtained from the handover measurement stage and the signalling bits from the repeaters the handover decision is made based on predefined handover criteria. The result of the handover decision-making stage is a decision on whether or not handover will take place and if so the handover target cell is chosen. In the handover execution stage, synchronization to the appropriate signal of the target handover cell is performed.

The cellular network structure for RA_handover is illustrated in Fig.6.

Fig.6 shows a seven-cell DVB-H network topology. Each cell contains six repeaters, i.e. six subcells, allocated uniformly around the border of the cell. R_{12} is one subcell in cell 1 at the border between cell 1 and cell 2. R_{21} is one subcell in cell 2 at the border between cell 2 and cell 1. Correspondingly R_{ij} and R_{ji} are the subcells at the border between cell i and cell j (i,j = 1,2,3,4,5,6,7) respectively. Suppose the repeaters are using directional antennas and each repeater can cover and only cover the subcell area where it is located. When the mobile receiver moves into any subcell area covered by a repeater, it will get the corresponding repeater information from the signalling bits it receives within the on burst time. At this location the receiver will begin to carry out handover measurement in the off burst time. This means that the receiver will not measure the signal strength using the off burst time until it reaches one of the subcell areas covered by a repeater. In this way the receiver does not need to measure the signal strength level constantly saving battery power. With the installation of the repeaters in the cell border area, the quality of service will also be increased compared with that of no repeaters installed in the border. Since broadcast cells are usually very large, some specific service information may need to be broadcast in part of the cell. The active repeaters proposed can be used to do this job. This provides an extra tool and outlet for the service management.

With MIMO (Multiple Input Multiple Output) antennas on the DVB-H receiver, the receiver can receive signals from different directions and combine them into a better quality signal, thus improving the quality of service. Take cell 1 of Fig. 7 for example, it is easy to see that another advantage of the RA_handover algorithm is that the receiver will always feel it is at the centre of the cell no matter wherever the receiver moves within the cell. In this way, the RA_handover algorithm can not only improve the quality of the service that the receiver receives but also keep the quality of the service consistent all over the cells.

With the addition of repeaters, the main transmitter power can be reduced, thus reducing the cost of the main transmitter. Although the addition of the repeaters will add to the cost of the network equipment, the overall cost of the system will not necessarily be increased when the increased quality of service and the savings on the terminal side because of reduced power consumption are considered.

Furthermore, the standardization of the handover algorithm in the DVB-H standard is not yet finalized. The RA_handover algorithm will provide a very competitive candidate for the selection of the handover algorithm to be incorporated into the standards of DVB-H.

IV. SIMULATION MODEL AND ANALYSIS

The performance of the RA_handover algorithm is analysed in this section with respect to the front-end battery power consumption, the received quality of service and the cost of the overall network system. The approach of this section is to build a simulation model in Matlab to identify the relationship between the received signal strength and the battery power consumption. The received signal strength is related to the repeater-covered area. The simulation scenario is that the repeater-covered area is changed as the received signal strength from the repeaters is changed. Cell radius, antenna height, transmitter power, transmission frequency and time percentage are the common parameters on which received signal strength depends. Time percentage is a term widely used in propagation modelling, it accounts for variations in hourly median values of attenuation due to, for example, slow changes in atmospheric refraction or in the intensity of atmospheric turbulence. The value of time percentage gives the fraction of time during which the actual received field strength is expected to be equal to or higher than the hourly median field strength. This variable allows the time variability of changing atmospheric (and other) effects to be specified. As the received signal strength can be thought of as proportional to the received quality of service, the relationship between the quality of service and the battery power consumption can be obtained. The simulation parameter data were derived from the DVB-H standards (ETSI, EN 300 744, 2004), (ETSI, EN 300 468, 2004), (ETSI, TR 102 401, 2005) and ITU standards (ITU-R P.1546-1, 2003).

Research has shown that human factors are an essential component of a successful service delivery system for wireless telecommunications (Young *et al.* 2005). Since cost is one of the human factors that are very important issue in business and standardization processes (Herath *et al*. 2005), the cost issue is described analytically in the last part of this section.

First, the percentage of battery power consumed using the RA_handover algorithm is compared with that of an algorithm in which every off burst time is used to make handover measurement as may happen without repeaters. For the network of Fig.7 it is easy to see that with the use of the repeaters the receiver will only make handover measurement in the six subcell areas instead of the whole area of cell 1. More handover measurements mean more battery power consumption. The handover probability can be obtained from the area where the handover will happen and the whole service area (Stijn 2003). By using the same methods, the saved power consumption can be calculated from the difference of the repeater covered area and the whole cell area. Suppose that the whole cell area and the repeater-covered area are ideal hexagonal shapes as shown in Fig.7 and the DVB-H receiver is uniformly distributed in both time and location in the cell. Fig.7 shows the maximum area the repeaters are able to cover. From Fig 7 it can be seen that the following equation holds:

$$S = \frac{A_c - A_r}{A_c} = 25\% \qquad (1)$$

In equation (1), A_c is the area of the whole cell, A_r is the whole area covered by the six repeaters, S is the saved battery power consumed by handover measurement compared with a handover algorithm utilizing every off burst time for handover measurement. Thus, 25% of the battery power consumed by handover measurement can be saved.

It is noted that in the network topology shown in Fig.7 the receiver will receive the best quality of service because it always feels it is at the centre of the cell. On the other hand Fig.7 shows the maximum area that the repeaters cover. In this case the saved battery power consumption of handover measurement *S* is a minimum. If the repeater covered area A_r is decreased, the saved battery power consumption *S* will be increased but the quality of service will be decreased. Because the receiver will not feel it is at the centre of the cell when A_r is decreased, the quality of the service will not be consistent all over the cell any more.

To identify the relationship between the battery power consumption of handover measurement
and the received quality of service a model is built up for simulation. Because the received quality of service is directly related to the received signal strength, it is supposed that there is a fixed linear relationship between the received quality of service *Q* and the received signal strength E_b:

$$Q = \alpha E_b \tag{2}$$

where the coefficient α is a constant parameter that links *Q* and E_b together.

Correspondingly, suppose that there is a fixed linear relationship between the battery power
consumed by handover measurement *S* and the repeater covered area A_r:

$$C = \beta A_r \tag{3}$$

where the coefficient β is a constant parameter that connects *C* and A_r together.

The repeater covered area or the range of the repeaters depends on several things, such as antennas and their height, expected reception quality, the propagation paths of signals, geographical location and terrain, presence of interference, receiver sensitivity and transmitter power. Given a receiver and a fixed location the adjustable parameters are the antennas and their height and the transmitter power. In this case, ITU-R P.1546-1 provides easy-to-follow procedures to calculate the field strength given antenna height and transmitter power (ITU-R P.1546-1, 2003).

ITU-R P.1546-1 is the ITU Recommendation for point-to-area field strength predictions for terrestrial services in the frequency range 30 MHz to 3000 MHz. Here land use only is considered. Based on the recommendation ITU-R P.1546-1, a simulation is built up in the following way:

Step 1: The dimensionless parameter k is calculated using the transmitter or repeater height h, as follows:

$$k = \frac{\log\left[\frac{h}{9.375}\right]}{\log(2)} \tag{4}$$

Where h is in the range 9.375 to 1200m; k is an integer in the range 0 to 7.

Step 2: An intermediate field strength E_u at a distance d from a transmitter of height h is calculated as follows:

$$E_u = p_b \times log\left[\frac{10^{\frac{E1+E2}{p_b}}}{10^{\frac{E1}{p_b}} + 10^{\frac{E2}{p_b}}}\right] \tag{5}$$

Where

$$p_b = d_0 + d_1 \cdot \sqrt{k} \tag{6}$$

$$E1 = (a_0 \cdot k^2 + a_1 \cdot k + a_2) \cdot \log(d) + 0.1995 \cdot k^2 + 1.8671 \cdot k + a_3 \tag{7}$$

$$E2 = E_{off} + E_{ref} \tag{8}$$

Where

$$E_{off} = \frac{c_0}{2} \cdot k \cdot k\left[1 - tgh\left[c_1 \cdot \left[\log(d) - c_2 - \frac{c_3{}^k}{c_4}\right]\right]\right] + c_5 \cdot k^{c_6} \quad (9)$$

$$E_{ref} = b_0\left[\exp\left[-b_4 \cdot 10^{\xi}\right] - 1\right] + b_1 \cdot \exp\left[-\left(\frac{\log(d) - b_2}{b_3}\right)^2\right] - b_6 \cdot \log(d) + b_7 \quad (10)$$

Where

$$\xi = \log(d)^{b_5} \quad (11)$$

In the equations in step 2 above a_0 to a_3, b_0 to b_7, c_0 to c_6, and d_0 to d_1 are parameters given in Table III. Because DVB-H is most likely to be used in UHF band (470-838MHz) and L band (1440-1790MHz) (Tyler 2005), only the transmitting frequency 600MHz (in UHF *band*) and (adjacent to L band for convenience) was used in the simulations with different time percentages (50%, 10% and 1%) for land area.

Step 3: The final field strength E_b at distance d from a transmitter of height h is:

$$E_b = p_{bb} \cdot \log\left[\frac{10^{\frac{E_u + E_{fs}}{p_{bb}}}}{10^{\frac{E_u}{p_{bb}}} + 10^{\frac{E_{fs}}{p_{bb}}}}\right] \quad (12)$$

In the above equation E_{fs} is the free space field strength under the assumption that the transmitter E.R.P. (Effective Radiated Power) is 1KW and E_{fs} is given by:

$$E_{fs} = 106.9 - 20\log(d) \qquad dB(\mu V / m) \quad (13)$$

P_{bb} in equation (12) is the blend coefficient set to a value of 8 because only the data for a blend coefficient of 8 is given in ITU-R P.1546-1.

The relationship between the receiver-received quality of service Q and the battery power consumed by handover measurement C can be expressed by equation (14) and equation

(15) below:

$$Q = \alpha \cdot f(h_1, h_2, h_3, l_1, l_2, l_3) \tag{14}$$

$$C = \beta \cdot g(l_1, l_2, l_3) \tag{15}$$

where l_1, l_2 and l_3 are the distances from the DVB-H receiver to the central main transmitter and the nearest two repeaters and h_1, h_2 and h_3 are the corresponding antenna heights of the central main transmitter and the nearest two repeaters.

Based on the field strength prediction procedures above a simulation model was built in Matlab.

For the simulation parameters: DVB-H cell radius is 30km; antenna height is between 9.375 and 1200m; transmission frequency is 600MHz, land path, 50% time, after simulation, the relationship between E_b and A_r obtained is shown in Fig.8. In Fig.8 h_i (i = 1, 2, …, 5) are the antenna heights of the main transmitter and the repeaters.

For simplicity suppose that α and β are both equal to 1, then the receiver-received quality of service Q as a function of the battery power consumed by handover measurement C for different antenna heights is shown in Fig.9. It is easy to see that the received quality of service Q increases with increasing battery power consumption C for a fixed value of cell radius, antenna height, transmitter power, transmission frequency and time percent.

Now the cost issue of the RA_handover scheme is considered. Active repeaters are expensive. On the other hand, the cost of the repeaters is connected with the cost of the main transmitter. To provide the same quality of service to users in the border area of the cell without repeaters it is necessary to install high power main transmitters which will be very costly. However, it is not very easy to get the exact cost of installing the repeaters and the main transmitters. Although it is hard to compare the exact cost of the RA_handover algorithm with that of an algorithm without the repeaters, it can be seen that by implementing the RA_handover algorithm a handheld DVB-H receiver can save a considerable amount of power consumption and improve the quality of service. This will drive the consumers' desire to use the DVB-H service, and thus the operator's profits. An exact cost comparison will be done in the future.

V. CONCLUSIONS

Handover for unidirectional broadcasting networks like DVB-H is a novel issue and a new challenge. Low power transmitters constituting dense multi-frequency cellular DVB-H networks could make handover a very important issue in DVB-H network planning and optimisation. This paper has proposed a novel approach for DVB-H receivers with MIMO antennas to decide when soft handover should occur, called RA_handover, based on a proposed intelligent repeater structure. Simple mathematical calculation showed that the RA_handover scheme could save 25% of the battery power consumed by handover measurement compared with a handover algorithm utilizing every off burst time for handover measurement as may happen without repeaters. A simulation model has been developed to show the performance of the RA_handover approach. Simulation results show that the receiver-received quality of service increases as the repeater-covered area is increased and that the maximum quality of service happens when the receiver always feels it is located in the centre of the cell. The cost issues introduced by the RA_handover algorithm were also analysed. Although it is still difficult to determine the cost of introducing the RA_handover algorithm, it has been shown that the cost will not be an obstacle to the implementation of the RA_handover algorithm when overall system costs and revenues are considered.

In the RA_handover algorithm, the repeaters are active repeaters. These repeaters can improve the quality of the services in the repeater-covered area as described in the paper.

The active repeaters can also add extra signalling information to the received signals. For the service providers, the extra signalling information can be used to signal the services or even additional localised services in the repeater covered area. This will provide an extra tool for the management of the provided services. Since RA_handover is a feasible handover algorithm for DVB-H, as demonstrated through simulation results reported in this paper, it is very promising for consideration by DVB group for eventual incorporation into the soft handover standard for DVB-H.

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Fig.1. Building Blocks of Passive and Active Repeater Configurations:

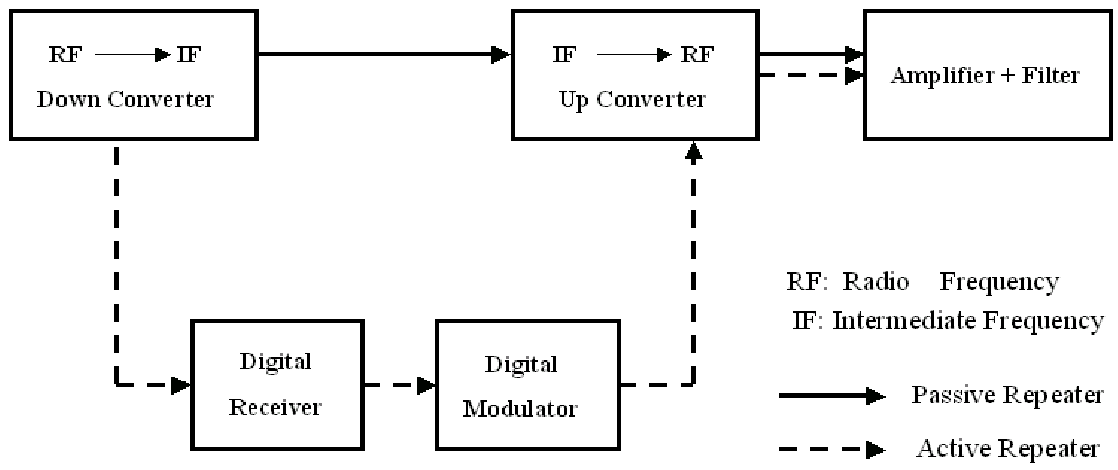

Fig.2 Time Slicing in DVB-H

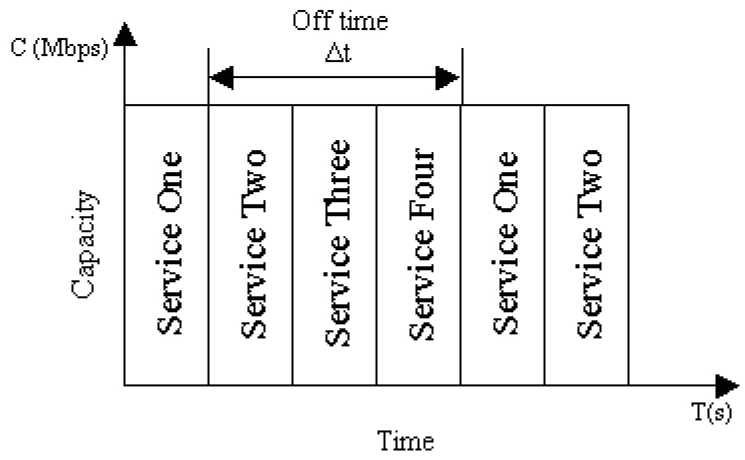

Fig.3 Soft Handover in DVB-H

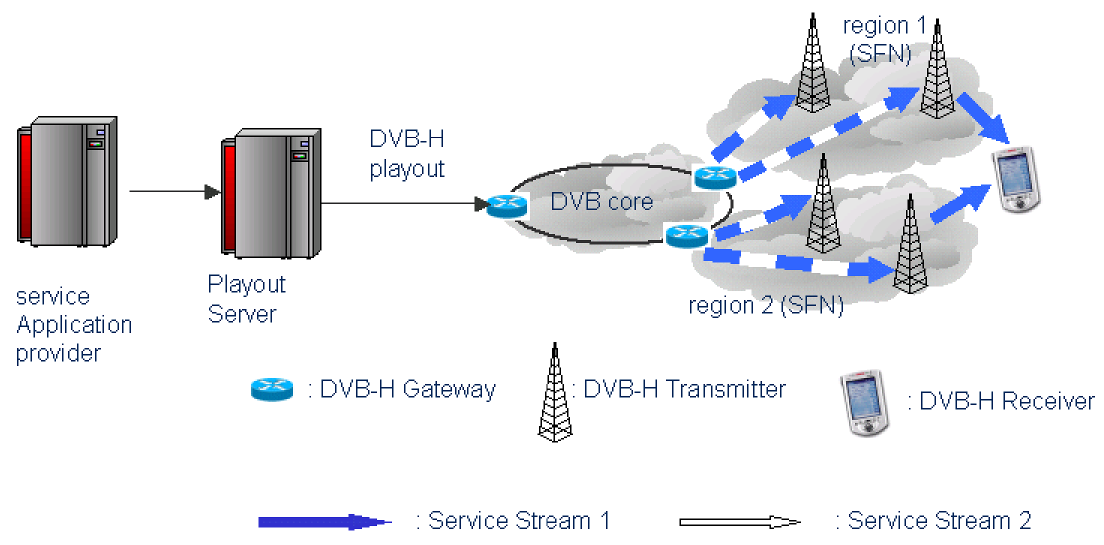

Table I: TPS Signalling Information for Handover

Bit number	Purpose/Content
S_1-S_{16}	Synchronization word
S_{40}-S_{47}	Cell identifier
S_{48}-S_{49}	DVB-H signalling
S_{50}-S_{51}	Handover types
S_{51}-S_{53}	Reserved for future use

Table II: Handover Related Information in NIT

Descriptor	Purpose/Content
Network_name_descriptor	Contains network name information
Service_list_descriptor	Contains services listings
Linkage_descriptor	Contains information accessing INT
Frequency_list_descriptor	Contain a list of frequencies for a transport stream
Cell_list_descriptor	Contains a list of cells and subcells including their coverage areas
Cell_frequency_link_descriptor	Contains a list of cells and frequencies used for the transport streams
Terrestrial_delivery_system_descriptor	Contains information about the centre frequency, bandwidth,code rate, etc.
Time_slice_FEC_identifier_descriptor	Contains information about the Time Slicing and MPE-FEC being used

Fig.4 Active Repeater Structure in RA_handover

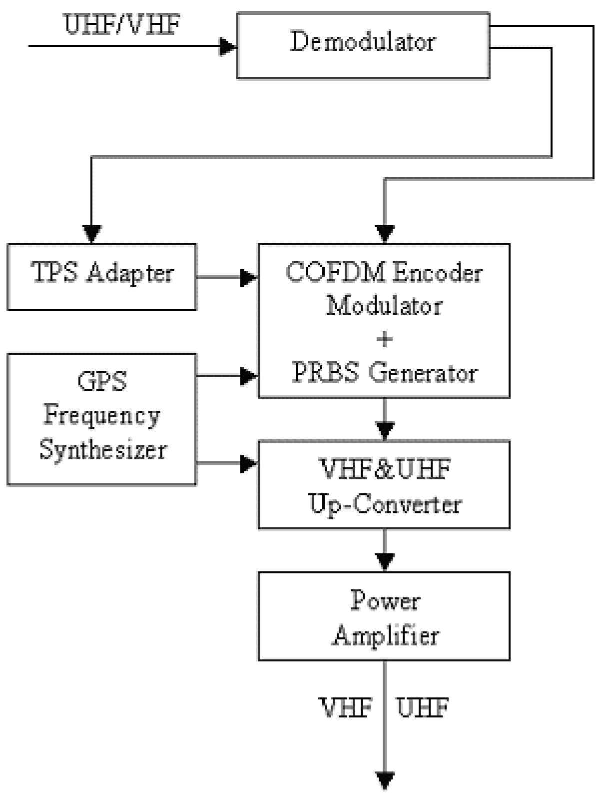

Fig.5 Components and Their Operations in RA_handover

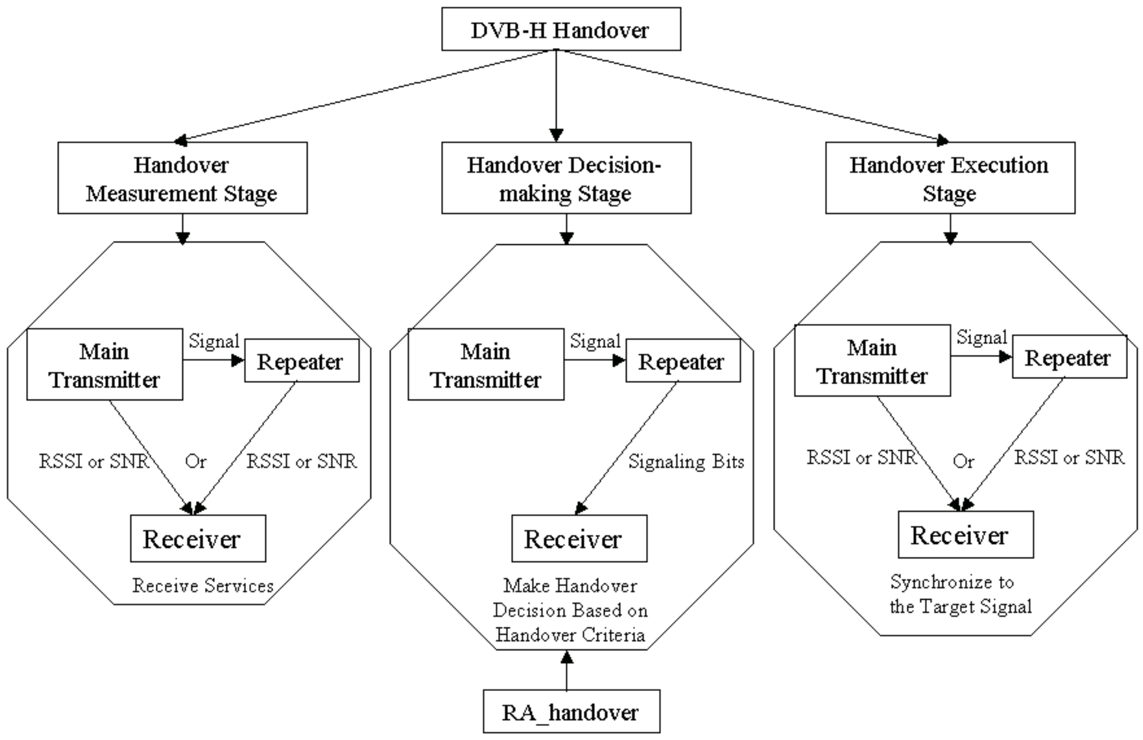

Fig.6 RA_handover Algorithm Cellular Structure

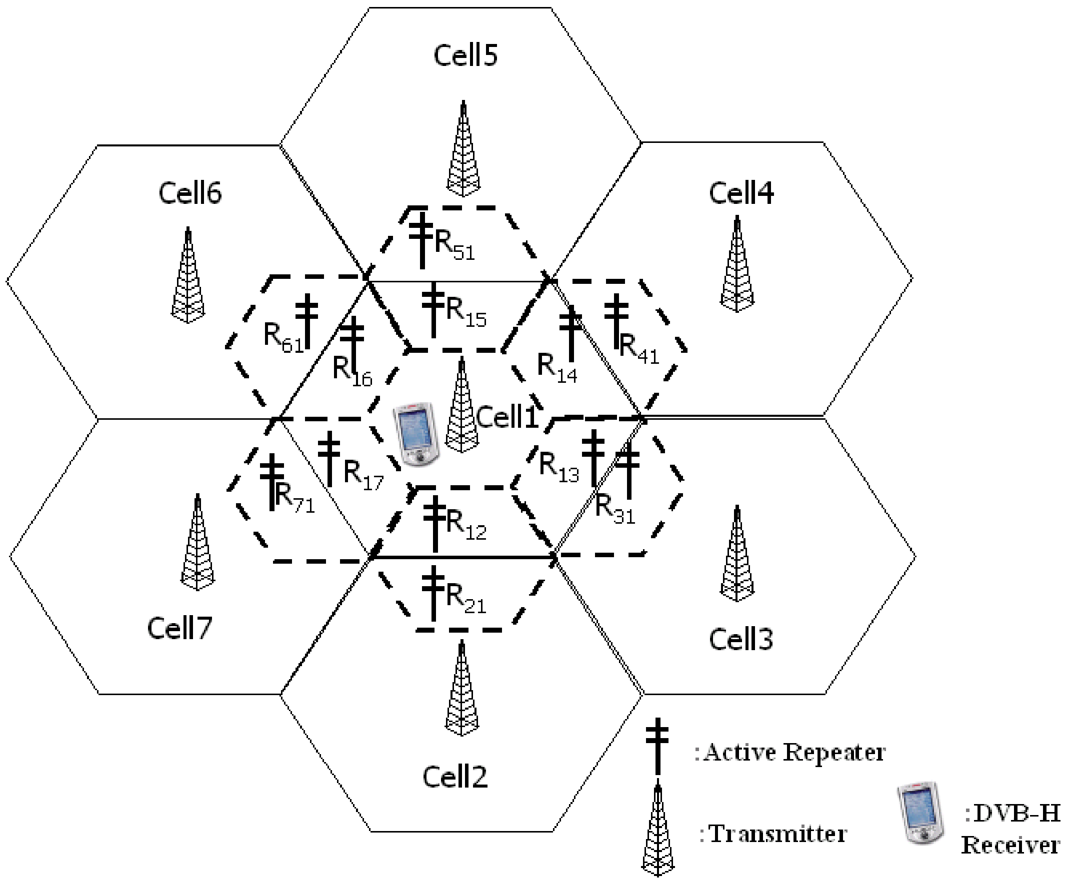

Fig.7 The Receiver Always Feels It Is at the Centre of the Cell

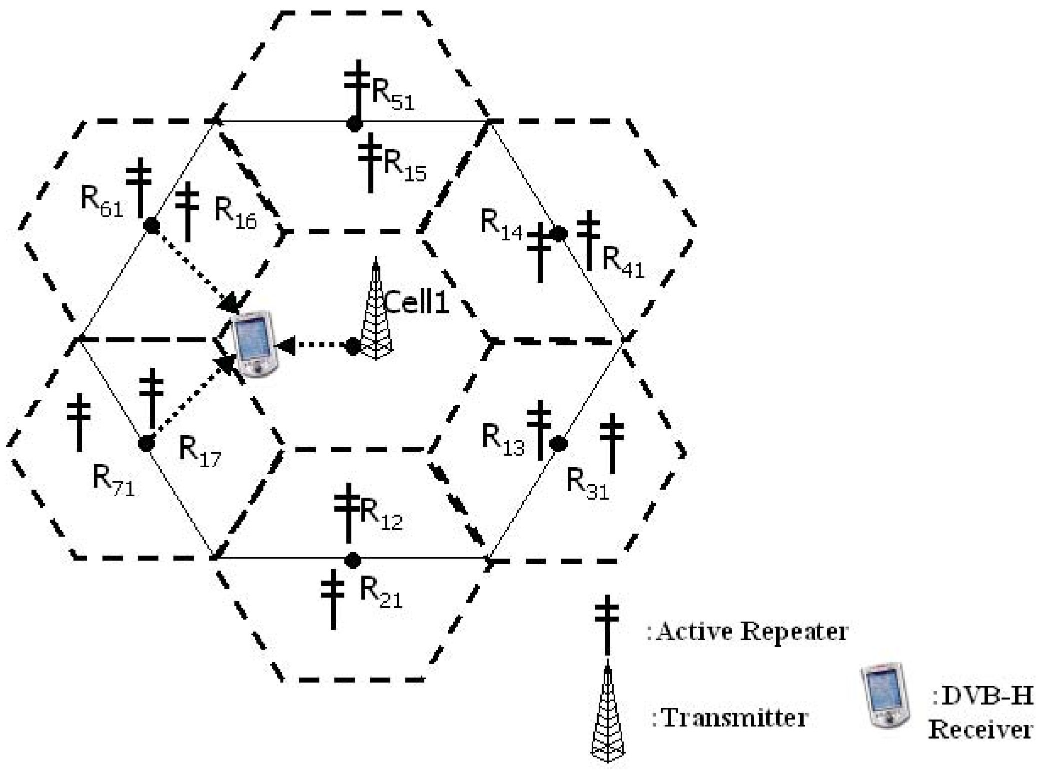

TABLE III: Coefficients for the Generation of The Land Tabulations

Frequency	**600 MHz**			**2 000 MHz**		
Time (%)	**50**	**10**	**1**	**50**	**10**	**1**
a_0	0.0946	0.0913	0.0870	0.0946	0.0941	0.0918
a_1	0.8849	0.8539	0.8141	0.8849	0.8805	0.8584
a_2	–35.399	–34.160	–32.567	–35.399	–35.222	–34.337
a_3	92.778	92.778	92.778	94.493	94.493	94.493
b_0	51.6386	35.3453	36.8836	30.0051	25.0641	31.3878
b_1	10.9877	15.7595	13.8843	15.4202	22.1011	15.6683
b_2	2.2113	2.2252	2.3469	2.2978	2.3183	2.3941
b_3	0.5384	0.5285	0.5246	0.4971	0.5636	0.5633
b_4	4.323×10^{-6}	1.704×10^{-7}	5.169×10^{-7}	1.677×10^{-7}	3.126×10^{-8}	1.439×10^{-7}
b_5	1.52	1.76	1.69	1.762	1.86	1.77
b_6	49.52	49.06	46.5	55.21	54.39	49.18
b_7	97.28	98.93	101.59	101.89	101.39	100.39
c_0	6.4701	5.8636	4.7453	6.9657	6.5809	6.0398
c_1	2.9820	3.0122	2.9581	3.6532	3.547	2.5951
c_2	1.7604	1.7335	1.9286	1.7658	1.7750	1.9153
c_3	1.7508	1.7452	1.7378	1.6268	1.7321	1.6542
c_4	198.33	216.91	247.68	114.39	219.54	186.67
c_5	0.1432	0.1690	0.1842	0.1309	0.1704	0.1019
c_6	2.2690	2.1985	2.0873	2.3286	2.1977	2.3954
d_0	5	5	8	8	8	8
d_1	1.2	1.2	0	0	0	0

Fig.8 The Relationship Between Received Signal Strength and Repeater Covered Area

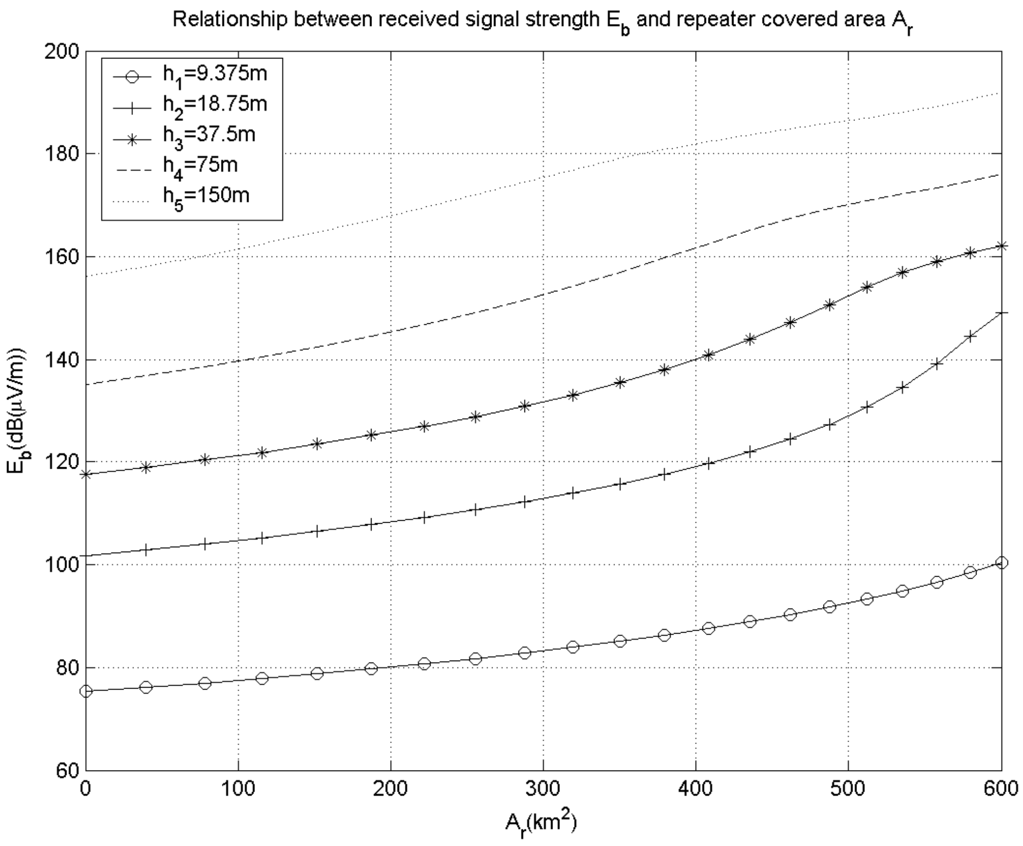

Fig.9 The Relationship Between Received Quality of Service and Consumed Battery Power