An Investigation of and a Proposal for Handover Decision-making in DVB-H

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Abstract — **Digital Video Broadcasting for Handhelds (DVB-H) is a standard for broadcasting TV like IP data content to portable devices, such as mobile phones, personal digital assistants (PDAs), laptops, etc. Handover in unidirectional broadcasting networks is a novel issue. Since making accurate handover decisions can reduce the battery power consumed, this paper proposes and investigates different strategies that can assist the handover decision-making process in DVB-H networks. The benefits and drawbacks of the different algorithms are presented. A hybrid handover decision-making algorithm is proposed. Future research directions for handover in DVB-H are suggested.**

Index Terms —DVB-H, Handover, Power consumption

I. INTRODUCTION

DVB-H is a standard specified by the DVB Organization specifically for the broadcast of TV-like content and data to handheld devices, such as mobile phones and personal digital assistants, which have unique requirements in terms of power consumption, screen-size and mobility [1]. Handover is the switching of a mobile signal from one channel or cell to another. When a user moves from one DVB-H cell to another, the DVB-H terminal has to be synchronized to another signal without service interruption. This paper defines handover in DVB-H as a change of transport stream and/or frequency.

Handover in DVB-H is rather different from handover in cellular telecommunications systems. This is mainly due to the unidirectional nature of DVB-H networks and the difference in the physical medium. Unlike DVB-T (Digital Video Broadcasting Terrestrial) [2], DVB-H transmits data streams using a burst mode called time slicing instead of a continuous mode. Time slicing is the characteristic that makes seamless soft handover in DVB-H possible. The time slicing transmission structure is illustrated in Fig. 1.

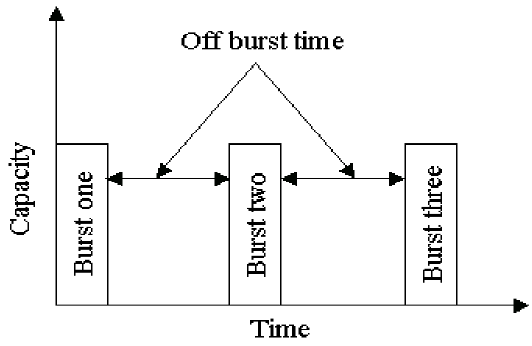

Fig.1. Time Slicing Structure

Depending on the transmission bit rate, the off time in the transmission stream can vary. The DVB-H receiver can use the off time to synchronize and initialize soft handover when it moves from one cell to another.

Handover in DVB-H consists of three stages: the handover measurement process, the handover decision process and the handover execution process. This paper focuses on the most important of the three stages - the handover decision process.

An instantaneous RSSI (Received Signal Strength Indication) value based handover scheme was proposed in [3]. This is the earliest publicly available handover algorithm for DVB-H.

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 of more off burst time used in handover measurement. Therefore, the RSSI value may have the chance of being measured many off burst times and the possibility is that the RSSI value would be measured at least every off burst time. Approaches to improve the RSSI handover algorithm are proposed in this paper. In the analysis of the potential battery power consumption savings of the algorithms proposed in this paper a worst case scenario for the RSSI value method is assumed of the RSSI value being measured every off burst interval.

A key idea in designing a soft handover algorithm for DVB-H is to predict the handover moment to reduce the handover measuring frequency saving battery power. This paper proposes and investigates different handover decision-making algorithms that would use battery power more efficiently than the RSSI algorithm. The advantages and drawbacks of the proposed algorithms are presented and the comparison between different algorithms is given. Based on this analysis, a hybrid handover decision-making algorithm is developed and future research directions for handover in DVB-H are suggested. The rest of the paper is organized as follows:

Section II presents different handover decision-making strategies and their benefits and drawbacks; some of the algorithms are evaluated using numerical simulation. The comparison between different algorithms will also be given in this section. In section III a hybrid handover decision-making algorithm is proposed. Its feasibility and benefits are shown. Section IV concludes the paper.

II. HANDOVER DECISION-MAKING ALGORITHMS

In this section, novel handover decision-making algorithms are proposed and investigated. Their benefits and drawbacks are presented.

A. Context Aware Handover Decision-making

Since the handover area is usually the border area between cells, the context aware handover algorithm tries to predict the time it will take the terminal to move from its current location to the border area. In this way, the terminal can know the moment it should make handover measurement reducing the time spent taking handover measurements. Two typical scenarios are considered, an urban scenario and a rural scenario. Suppose the radius of the DVB-H cell is R (km), the distance between terminal and the transmitter station is L (km), and the velocity of the terminal is V (km/sec). Then the time it takes for the terminal to move from its current location to the handover area is given by:

$$T=(R-L)/V \quad (1)$$

R can be known in advance and obtained in the network planning stage. L can be roughly calculated from the signal strength measured by the receiver at the current location and the signal loss properties of the transmitted power. V can be estimated according to the specific environment, urban or rural. Such parameter information about the environment can be broadcast in the cell periodically so that when the terminal enters a cell it gets this information. The terminal can then determine the signal strength after the time interval T instead of measuring RSSI constantly. If the time between successive bursts of interest is denoted by Δt, since the RSSI handover scheme takes measurements every Δt seconds and usually $T>>\Delta t$, the number of measurements needed for handover will be far less in the context aware handover scheme.

The graph illustration is shown in Fig. 2 and the steps that need to be taken to implement the context aware handover decision-making algorithm are:

Step 1: The DVB-H receiver extracts its environment context information from the received service streams.

Step 2: According to the environment context information received, the DVB-H receiver estimates its velocity and the DVB-H cell radius.

Step 3: The DVB-H receiver estimates its distance from the transmission base station of the cell it is located in.

Step 4: Using equation (1), the DVB-H receiver calculates the time interval T to soft handover measurement.

As the environment context is divided into urban and rural scenarios only, the handover measurement interval T will not change frequently keeping the power required low. If the environment context is divided into more categories, the handover will be more accurate but the battery power consumed will be higher because of the increased computing complexity.

A numerical simulation was used to evaluate this algorithm as follows:

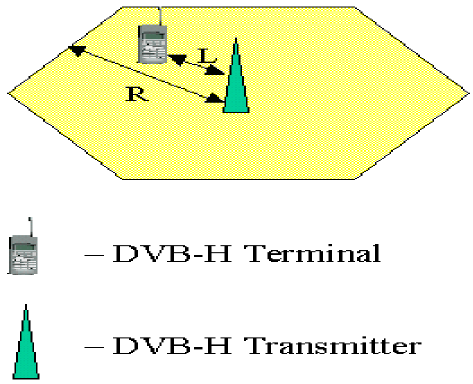

Fig.2 Context Aware Handover

In the urban scenario, the user's velocity is usually below 48 km/hour. Suppose the typical DVB-H cell radius in an urban area is 20 km, then the average value of T = [20/ (2*48)]*3600=750secs. In the rural scenario, the user's velocity is usually about 96 km/hour. Suppose the typical DVB-H cell radius in a rural area is 40 km, then the average value of T = [40/ (2*96)]*3600=750secs.

So typically the DVB-H receiver needs only measure the RSSI about every 750secs. This period is much longer than the off burst time that is at most a few seconds [3].

Consider a worst-case example. A user is driving along a road in rural area. The user's speed is 112km/hour. Suppose the user is using a DVB-H receiver and the radius of the DVB-H cell along the road is 40km. Suppose the user switches on the DVB-H receiver near the cell border area, for example 39.8km from the DVB-H transmitter base station. This DVB-H receiver's measuring interval is [(40-39.8)/112]*3600=6.4 sec.

The off burst time depends on the service being used and the burst bit rates. According to [3], the typical off burst time is about 3 seconds. The burst duration is usually much shorter than the off burst time. Suppose the burst duration is less than 1 second and the RSSI value is measured every off burst time, in this case, the RSSI handover scheme measuring interval Δt will be less than 4 seconds.

Using the context aware handover decision-making algorithm, in the worst case example described above, about [(6.4-4)/4]*100% = 60% of the battery power used by the RSSI value based scheme is saved; Because of the low computational complexity of equation (1), the context aware handover decision algorithm will consume very little power in the handover decision-making process.

The drawbacks of this algorithm are that the estimation of distance and velocity may not be very accurate. So this single algorithm cannot adapt to complex environments.

B. Location Aided Handover Decision-making

This algorithm uses mobile location information to aid the handover decisions in DVB-H especially in the motorway scenario.

The handover scenario considered is illustrated in Fig. 3.

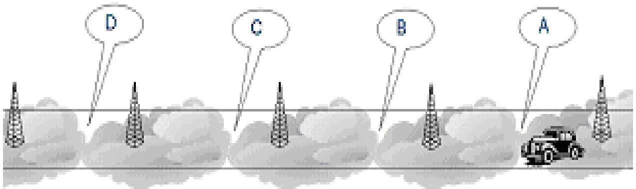

Fig. 3: Handover on Motorways for DVB-H

Fig. 3 denotes a car running along a motorway from right to left. Suppose DVB-H transmitters are located along the motorway and that the DVB-H cells cover the entire motorway. It is assumed that the receiver will not receive stronger signals from a cell other than the cell in which it is located except in a cell border area. These assumptions make it easy to describe the model and do not affect the algorithm. Suppose A, B, C, and D in Fig. 3 are the positions where the DVB-H receiver inside the car performs the handover.

The main idea of this location aided handover decision algorithm is that the handover will not be initiated until the car reaches a handover position, that is, A, B, C, or D in Fig. 3. In this case, the receiver will not use any of the off burst time for measurement until it reaches a handover position staying inactive most of the time and saving battery power.

The crucial question is how the receiver can know whether it is in a handover position or not. Different techniques can be used to provide location information to the receivers. The most widely used location technique is Satellite Positioning Systems (GPS, GLONASS, Galileo) [4, 5].

The evaluation of this algorithm is as follows:

The vehicles on a motorway can be assumed to be an M/M/1 queuing model because the following assumptions are met:

- Total number of vehicles driving on the motorway is very large.
- A single vehicle uses a very small percentage of the motorway resources.
- The decision to join the motorway is independently made by each vehicle.

The above observations mean that assuming a Poisson arrival process will be a good approximation of the vehicles passing the handover positions on the motorway. Although the distance between successive handover locations can be assumed to be constant because of the uniform motorway features, the individual vehicle speed is fluctuating because of the varying traffic. So the time interval between successive handover positions is variable. In this handover decision algorithm, the receiver making measurements can be modelled using a simple M/M/1 queuing model as shown in Fig. 4. In this model, the vehicle can be taken as the server; the handover positions can be taken as unlimited customers arriving at the server randomly.

The states of the queuing system are assigned to discrete handover locations along the road. The number of cells along the motorway route determines the number of states in the model.

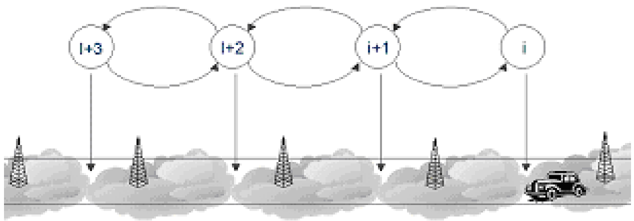

Fig. 4: Handover Algorithm based on M/M/1 Model

The transmission probability of the model λ can be calculated using the average vehicle speed v and the distance between successive handover positions l: $\lambda=v/l$. The average vehicle speed v can be obtained according to the speed limit of the road. The distance between successive handover positions l can be obtained according to the cell diameter. It is assumed without loss of generality that the vehicle travels on a fixed route and the bi-directional traffic is represented by two models one for each direction. In Figure 4, the state transition of our model is only from right to left. In this model, the probability of arrival at a handover location is the probability of the vehicle reaching a new cell.

Suppose that the average cell diameter is l = 10 Kilometers and the speed limit on the motorway is v = 90 kilometers/hour. Then λ = 90/(10*3600) = 0.0025. The average inter arrival time will be T = 1/ λ = l/v = 400seconds. Because the time the user is in the handover position, that is the service time, is very short, suppose it is 10 seconds, then this algorithm will save up to 400/(400+10) = 97% of the battery power consumed by measuring the RSSI value every off burst interval. It is easy to see that the bigger the cell size and the slower the vehicle speed, the more of the battery power used by the RSSI algorithm will be saved.

The drawback of this algorithm is that incorporating Satellite Positioning Systems components into the handset will make the handset more expensive and usually Satellite Positioning Systems do not provide location assistance indoors. Thus, this algorithm is only suitable for the motorway scenario or vehicle based DVB-H receivers.

C. UMTS Aided Handover Decision-making

Handover decision-making in DVB-H can be assisted by the terminal's UMTS link if a converged UMTS and DVB-H network serves the terminal. This kind of converged network structure is described in detail in [6]. The converged network structure is taken from [6] and shown in Fig. 5. In this scenario, there are always UMTS base stations located in the DVB-H cell border area because the DVB-H cell is much larger than the UMTS cell. When the terminal moves to the DVB-H cell border area that is the handover position area, the UMTS base station in the handover position area will inform the hybrid UMTS/DVB-H terminal that the DVB-H handover measurement should be performed.

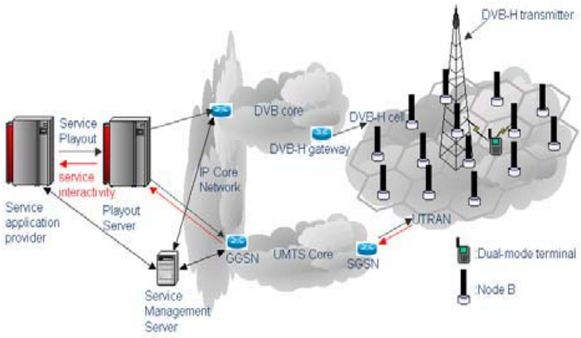

Fig. 5: Converged DVB-H and UMTS Network Structure

The performance of this handover decision-making algorithm depends on the performance of the UMTS connection of the terminal. The terminal moving into the DVB-H handover area also makes handover in the UMTS network from one cell to another compulsory. If the UMTS cell that is the DVB-H handover area is too crowded the UMTS handover request may be blocked when the terminal moves into the handover area. The handover failure probability is the main performance criteria of this algorithm. To avoid handover failure, cell broadcasting [7] can be used to provide the handover measurement initialization information to the terminals that move into the handover area. The battery power consumption reduction compared with the RSSI algorithm depends on the UMTS cell size in the handover area compared with the DVB-H cell size. It is obvious that the smaller the UMTS cell size and the bigger the DVB-H cell size, the more battery power consumption can be saved.

The drawback of this algorithm is that the DVB-H handover accuracy and reliability depends solely on the UMTS base station in the handover area. So the algorithm's complexity is increased.

D. Repeater Aided Handover Decision-making

Repeaters have been important network components for both analogue and digital TV broadcasting [8]. In the planning and optimization of DVB-H networks, a repeater could be used to extend the transmitter coverage area or to cover a shadow area, such as a tunnel, valley, indoor area, etc. There are usually repeaters in a cell border area. In this handover decision-making algorithm intelligent repeaters are used to provide location information to the receivers. When such repeater specific information is delivered to the receiver within the service streams, the receiver will perform the handover measurement at the right moment. Details of this algorithm are presented in [9] where it is shown that using this algorithm up to 63.22% of the average front-end battery power consumption of measuring RSSI value every off burst interval could be saved.

The main drawback of this algorithm is that new intelligent repeaters must replace the old repeaters in the cell border areas. The expenses of installing such new repeaters must be considered by the network operator.

E. Other Handover Decision-making Algorithms

Since the key idea of all the different handover decision-making algorithms for DVB-H proposed in this paper is to predict the handover moment, the more accurately the handover moment is predicted the better the handover decision-making algorithm is. There are some other handover decision-making algorithms potentially available. Pattern recognition is an example of a technique that could be used to assist in making accurate and timely handover decisions. A Hidden Markov Model (HMM) based algorithm is proposed here as an example of the possible use of pattern recognition techniques in handover decision-making in DVB-H.

Similar Hidden Markov Models have been proposed for cellular GSM networks [10]. The proposed algorithm utilizes Hidden Markov Models trained with previously collected data to model the strength of the received signals for different DVB-H cells. The strength of the received signals is measured from the received service signals without occupying the off burst time. Then the terminal uses the received signal strengths to decode the Hidden Markov Model of the cell it is located in. When the terminal is near the cell it is moving to, it perceives the change in the Hidden Markov Model. Then it makes the decision to perform the handover measurement. The basic idea of this handover decision-making algorithm is illustrated in Fig. 6.

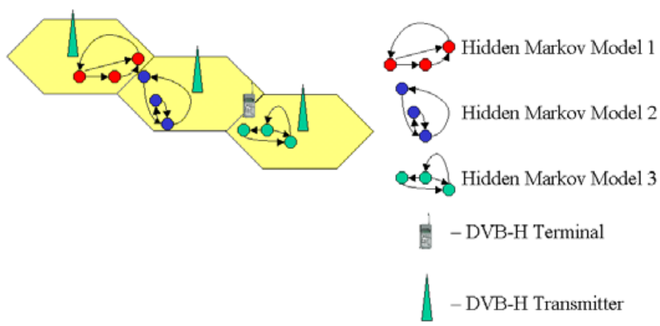

Fig. 6: Hidden Markov Model Based Decision-making Algorithm

This algorithm requires no modifications to existing standards or DVB-H handsets. Therefore, it may lead to cost effective, reliable solutions. Since this algorithm is based on the previously collected data that are the received signal strength measurements, the prediction precision is the most important factor for its success. The drawback of this algorithm is that when the terminal is idle most of the time, it cannot get enough measurement data for accurate model prediction.

F. Comparison of Different Handover Decision-making Algorithms

The power consumption of the proposed algorithms is compared with RSSI algorithm. The comparison is shown in Table 1.

TABLE I
COMPARISON BETWEEN DIFFERENT ALGORITHMS

Algorithms	Saved power consumption compared with RSSI algorithm	Advantages	Disadvantages
Context aware	60% in the worst case	Simple and efficient	Less robust to environment
Location aided	Up to 97%	Simple and efficient	Costly and only in motorway scenario
UMTS aided	Not determined	Simple and efficient	Complex and needs UMTS network
Repeater aided	Up to 63.22%	Simple and efficient	Costly
HMM based	Not determined	Simple, less costly, efficient	Needs enough measurements data

III. HYBRID HANDOVER DECISION-MAKING ALGORITHM

Implementing one handover decision-making algorithm has the limitation that the algorithm may work well in one specific environment but not all environments. The future mobile service is an anytime anywhere service. The terminal will be used in all kinds of environments. In this case, implementing one algorithm is not enough. A hybrid handover decision-making algorithm is thus proposed in this paper.

The basic idea of this hybrid algorithm is that a central management module manages the different algorithm modules installed in the terminal as illustrated in Fig. 7.

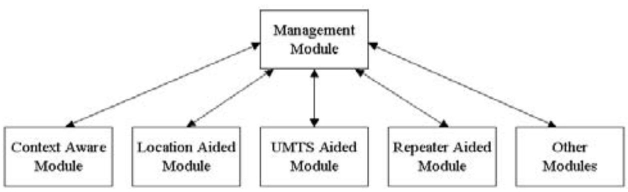

Fig. 7 Hybrid Algorithm Modules

The hybrid algorithm is:

Step 1: The DVB-H receiver extracts environment context information from the received service streams.

Step 2: According to the environment context information, the DVB-H receiver chooses a handover decision algorithm as follows:

1: The management module chooses an algorithm at random.

2: The performance of the chosen algorithm is evaluated and a score or grade is assigned by the management module.

3: When the receiver is switched on the next time one of the algorithms that have not yet been used is selected at random and step 2 applied.

4: After many algorithm evaluations, the best performing algorithm for each environment is identified. These algorithms are chosen as the default algorithms for the respective environment.

In this hybrid algorithm, the environment information is divided into different categories, urban residential area, rural residential area, pedestrian area, motorway area, etc. These detailed categories of different environment need to be defined and evaluated in real field trials. The evaluation of this hybrid algorithm is the subject of future research.

IV. CONCLUSIONS

The critical phase in the DVB-H handover procedure is the handover decision-making process. A good handover decision-making algorithm can greatly save consumed handset front-end battery power. Novel DVB-H handover algorithms have been proposed and investigated in this paper. However, the different algorithms have different limitations. A hybrid handover decision-making algorithm has been proposed to utilize the advantages of the different algorithms while avoiding their limitations. Although this hybrid algorithm has not been evaluated, its potential feasibility in real environment has been made clear. For validation the different handover algorithms proposed should be tested in the field.

ACKNOWLEDGEMENT

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