2

Motivation and Approaches

2.1 Motivation

This section presents the context that created handover issues in DVB-H networks. Before talking about the origin of the handover issues in DVB-H it is necessary to take a look at the services that are transmitted in DVB-H networks. The service contents in DVB-H networks are delivered in the form of IP-packets using IP-based mechanisms or in the form of other network layer datagrams encapsulated into Multi Protocol Encapsulation-sections (MPE-sections) [67, 134]. This kind of service is called IP Datacast (IPDC) [53]. IPDC was developed by the DVB ad-hoc group Convergence of Broadcast and Mobile Services (CBMS) [53] over the DVB-H standard [93]. The IPDC over DVB-H standard complements the DVB-H standard by defining OSI layers 3-7 and refining some of the OSI layer 2 specific protocols, especially Program Specific Information (PSI) and Service Information (SI). Although IPDC services can be offered via existing GPRS or UMTS cellular networks by MBMS [135, 96], MBMS is only suitable for light traffic services such as short video clips. For a heavy duty service like streaming using H.264 video encoding, QVGA format, 25fps and 384kbps, DVB-H is a better solution. This is largely because of that DVB-H is a broadcasting technology with up to 10 Mbps bit rates depending on the modulation parameters [160]. IPDC brings new characteristics for DVB-H networks. The benefits are as follows [68]:

1. IPDC provides a platform for true convergence of services between DVB-H and cellular telecommunication networks (GPRS/UMTS).
2. IPDC allows the coding to be decoupled from the transport layer, that is, all the different coding techniques can be used above the UDP/IP (User Datagram Protocol/Internet Protocol) layer, thus opening the door to a number of features benefiting handheld mobile terminals including a variety of encoding methods, which only require low power from a decoder (Decoding high bandwidth MPEG-2 encoded streaming video/audio is relatively power consuming).

3. IPDC is relatively insensitive to any buffering or delays within the transmission (unlike MPEG-2), this is because IPDC is utilizing IP protocol which has long been developed upon the non-quality-assured Internet environment.

4. IPDC is well suited for time-sliced transmission.

Because the mobile handover environment in DVB-H is as challenging as the non-quality-assured Internet environment, an IPDC service is suitable for handover in DVB-H.

VALIDATE and MOTIVATE are two European projects that addressed the issues of mobile reception of DVB-T signals [2]. Laboratory tests and field trials have shown that mobile applications of DVB-T are feasible using the code rate = 1/2 modes of the specification [136] which uses more resources than the code rate 3/4. But tests of receivers also showed the limits of performance achievable for mobile television without enhancements to the receivers [97]. In addition, the power consumption of mobile reception of DVB-T is a big issue for battery powered terminals [3, 98].

DVB-H is the technique that was rolled out for the mobile portable reception of IPDC contents [137, 142]. Similar standards are used in Japan and Korea for mobile data broadcasting [143, 4]. The achieved transmission bitrate is lower for mobile reception compared with that for static reception because of the challenging mobile environment. Therefore, the transmission power has to be higher to achieve an acceptable quality for user to view if an assumption is made that the high transmitted power will make it easier for the terminals to decode the received signals. It has also been shown that in general the maximum speed for mobile DVB-T reception in single frequency networks (SFN) is lower than in Multi-Frequency Networks (MFN) for the same set of parameters [99]. Low power DVB-H transmitters offer the possibility of multi-frequency cellular structured DVB-H networks for the broadcast of localized services. One network scenario is to co-locating the DVB-H and 3G UMTS transmitters where the cell size of DVB-H is usually smaller than that of the stand-alone DVB-H transmitters. Smaller cell size for DVB-H provides desirable opportunities for the provision of localized services. With smaller cell size, handover in DVB-H becomes a critical issue. Some research has been done about handover in multi-frequency cellular structured DVB-H networks [68, 104].

Handover in traditional cellular telecommunications networks (like GSM) refers to the mechanism that transfers an ongoing call from one cell to another as a user moves through the coverage area of the cellular system [38] and has long been a research topic. However, handover in DVB-H refers to the switching of the reception of IP based services from one transport stream to another when the terminal moves through the coverage area of a DVB-H network [67].

Soft handover is usually used to mean that radio links are added and removed in such a way that the device always keeps at least one radio link to the base station [106], thus no service interruption happens. In DVB-H, this means that the received frequency and/or transport stream is changed without interruption of the on-going reception.

A stationary DVB-H terminal can assume that a transport stream on a given frequency will be constantly available during its operation. However, DVB-H is mainly for mobile portable terminals and a mobile terminal will face the situation that the selected transport stream signal is no longer available on the tuned frequency if the terminal is moving out of the reception area. In order to continue the selected service, the mobile terminal then needs to automatically select and tune a different frequency carrying either exactly the same transport stream or a different transport stream containing the same service.

If the mobile terminal moved from one cell to another cell of the same network, the same set of transport streams could be available and if available they will be on different frequencies. The mobile terminal has to determine on which frequency the lost transport stream is transmitted in the entered cell [69].

If the mobile terminal moves from a cell belonging to one network into a cell of another network then the lost transport stream is not necessarily available. In this case the mobile terminal might want to find out if the service that had been selected before is still available on some transport stream of the entered network or if there are alternative services to select. Therefore, two situations exist:

1. If the previously selected service is still available, the mobile terminal needs to determine the transport stream that carries the service and the frequency of that transport stream in the entered network.
2. If the service is not available, the mobile terminal might try to select an alternative (which could be a local variation of the original service or an associated service) before it prompts the user for a decision. Deploying this mechanism, co-operating networks might provide automatic handover between services of similar program type or services that provide additional information such as traffic announcements.

Fig. 2.1 shows the two handover situations presented above: handover from one cell to another cell of the same network (within DVB core network 2) and the handover between cells of different networks (from DVB core network 1 to DVB core network 2). The DVB core network is usually an IP network. Such an IP network is owned or rented by a network operator. It is set up to transmit the services generated by the service application providers to the radio access networks (the IP-to-DVB encapsulators and the DVB-H transmitters). The DVB core 1 and DVB core 2 in Fig. 2.1 are not connected each other because each DVB core network is operated by a different network operator in the case shown in Fig. 2.1. Regarding these two different kinds of situations, from the application point of view, handover for DVB-H can be divided into Physical

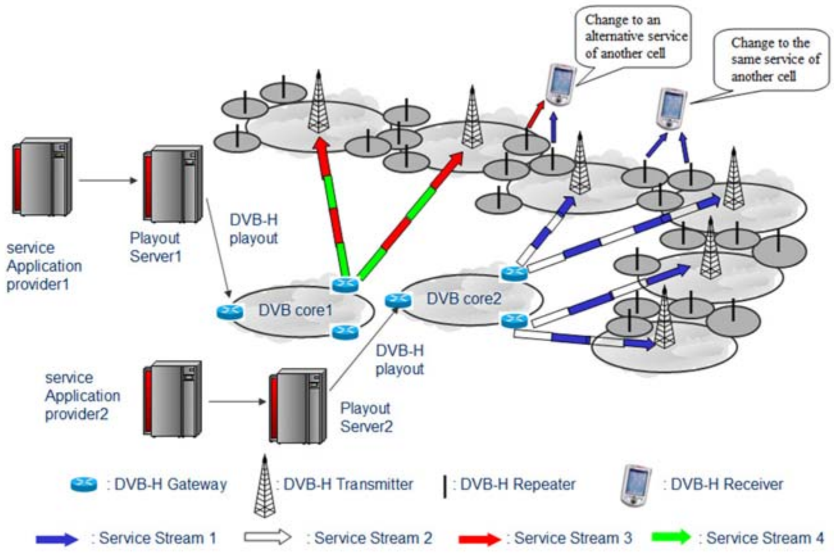

Fig. 2.1. General Handover Situations in DVB-H Networks

Handover and Service Handover depending on whether or not the service is changed.

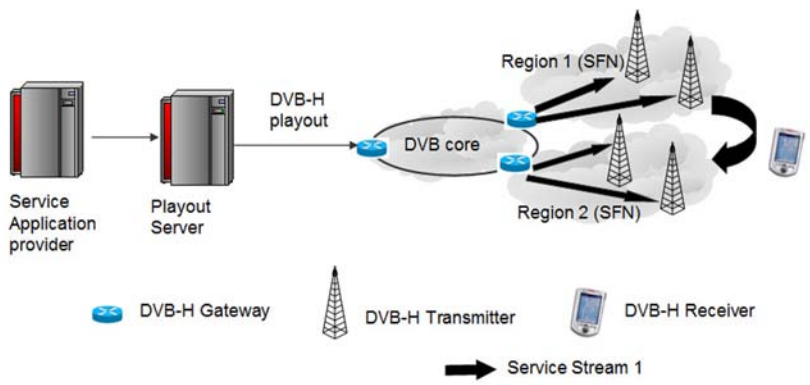

Fig. 2.2. Physical Handover Illustration

Physical handover is shown in Fig. 2.2. In this case, the terminal moves from one DVB-H cell to another without the received service being changed. However, the transmitter frequency sending the transport stream changes.

Service handover is shown in Fig. 2.3. In this case when the receiver moves from one cell to another, it begins to receive a transport stream that is different from the one it received in the original cell.

DVB-H is intended to carry IP data services. In order to provide diverse IP data services it is expected that a DVB-H cell will usually be smaller than a DVB-T cell [100]. There are also other reasons why a DVB-H cell is usually smaller than a DVB-T cell. They are low-gain DVB-H receiver antenna, low height of DVB-H transmitter antenna, building penetration losses for DVB-H indoor reception and fast fading in a mobile environment [100]. Thus, low power transmitters serving a network operating in a multi-frequency network (MFN) mode, in networks composed of one or more Single Frequency Network (SFN) areas or a mixture of these two topologies are the main network structure types for DVB-H.

One of the main factors that effect the selection of the network topology is the need for localized services. Depending on the density of the localized services, the network topology can vary from a MFN composed of single transmitter cells to networks composed of one or more SFNs. If localized services are not supported at all within the network, the whole network can consist of a single SFN where handover is not needed. All other network types, except the network type of a single SFN, result in handovers. The handover frequency in this book refers to the number of handovers required for a DVB-H receiver in its power-on duration. It is dependent on the size of the cells, terminal mobility, and environmental factors (such as rural or urban) which are similar to those in UMTS/GSM, etc. As low power transmitters serving a multi-frequency cellular structured network are expected to be a typical network structure for DVB-H, handover becomes a critical issue.

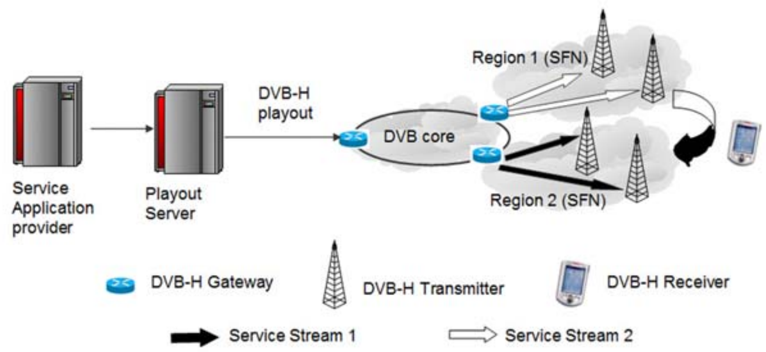

Fig. 2.3. Service Handover Illustration

Handover is the switching of a mobile signal from one channel or cell to another. For DVB-H, this chapter defines handover as a change of transport stream and/or frequency. In this chapter the two different terms "channel and transport stream" are used for the same meaning. They all mean the path along which a communications signal is transmitted.

The handover schemes for DVB-H are soft handover because of the existence of time slicing.

It must be noted that the handover categories may overlap. For example a soft handover can be both a service handover and an active handover at the same time.

2.2 Approaches

There are different ways to address the handover problem in DVB-H. Some of the handover algorithms in other networks, such as the handover in telecommunication networks and the handover in mobile IP network, can even be borrowed and taken as a reference in the DVB-H networks. The handover issue for DVB-H in this book is approached from two aspects: the handover stages of a DVB-H handover and the handover challenges that need to be addressed for a DVB-H handover.

2.2.1 Handover Stages

Handover in DVB-H consists of three stages: handover measurement, handover decision-making based on the handover criteria, and handover execution [112]. All the previous research work on handover in DVB-H can be categorized into or was targeting these three stages.

A. Handover Measurement

Handover measurement is the first of the handover stages. In DVB-H the handover measurement takes place in the off time of the time slicing mode. The terminal will switch off the tuner and the demodulator in the off burst period. However, the front-end receiver has to keep measuring the signal strength from neighbouring transmitters to monitor the signal strength fluctuation. If the signal strength of the received signal is degraded to some degree, the handover decision-making process will be triggered. The wake up time for the next burst will be signalled in the current burst period. The detailed procedure is given in [104].

B. Handover Decision-making Based on the Handover Criteria

In the second stage of the handover process, the DVB-H terminal will decide whether it should perform handover based on the pre-defined handover criteria. The most commonly used handover criteria are the Received Signal Strength Indicator (RSSI)and the Signal Noise Ratio (SNR) [104, 106]. When the RSSI or the SNR is identified as degraded to some degree from the handover measurement of the first stage, the handover decision-making process will be triggered. Taking the SNR as the handover criteria for example, once the SNR threshold margin value *s_th* is reached for a certain threshold time *t_th*, the receiver will tune to the frequency with the strongest SNR value to continue service reception. The SNR and the duration threshold is shown in Fig. 2.4. Fig. 2.4 was obtained from the simulation conducted in [106]. In Fig. 2.4 the DVB-H terminal is receiving the signal from subcell 1 from the beginning. At time 12 the terminal begins measuring the signal from subcell 2. After time duration t_th the terminal will handover to the signal from subcell 2 at around time 13.5. In addition to the physical layer parameters, it is increasingly important to take the quality of currently received IP streams as one handover criterion especially within a MFN network. This is also recognized in [42] and in [68].

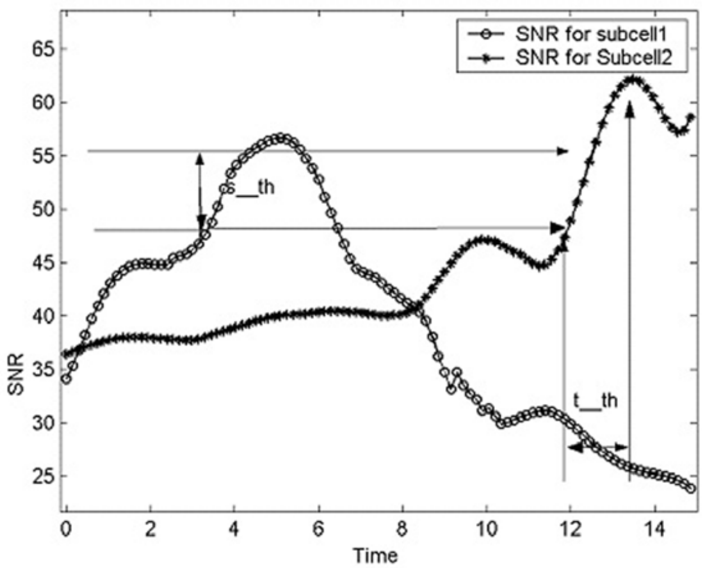

Fig. 2.4. SNR And Time Threshold For Handover Decision Making

C. Handover Execution

Handover execution is the last stage of the handover process. After the terminal has made the handover decision it will perform the handover execution stage. In this stage, the terminal attempts to synchronize to the handover target signal and to continue the reception of the currently received services without interruption. In order to validate whether the handover target signal is the correct one, the DVB-H signalling information contained in the TPS bits and the PSI/SI tables will be utilized. The handover execution stage is a frequency and transport stream synchronization stage. It consists of frequency synchronization using the TPS bits and PSI/SI tables and transport stream synchronization using the PSI/SI tables [105, 113, 73]. After the terminal has tuned to the correct frequency and transport stream, the terminal need also select the correct service (e.g. the consumed program) from the transport stream according to its obtained information within the received time slice.

2.2.2 Handover Challenges

Some challenges may exist in the handover process of DVB-H if the handover algorithm is not designed efficiently such as the *Ping Pong* effect, "fake signals" or tuning failure, excessive power consumption and packet loss. These are the challenges for DVB-H handover in general and the designed algorithms should cope with them. Also the network planning has big a effect on handover in DVB-H, as different network topologies decide whether a DVB-H handover is needed and how often is it needed.

A. Ping Pong effect

Because the signal strength fluctuates in the real physical environment the DVB-H receiver has the possibility of detecting strong signals from other cells even though it is located in the original cell, especially in the transmitter shadow areas. For example, when high buildings are blocking line of sight signal transmissions. In this case, the receiver may have the possibility of repeated handover between different cells, causing a *Ping Pong* effect [106]. Since frequent handover increases power consumption that is critical for battery powered handheld terminals, reducing the occurrence of the *Ping Pong* effect is one of the key research areas for handover in DVB-H. Since whether and when a handover should be performed is determined in the handover decision-making stage, the *Ping Pong* effect should be reduced to the minimum possible by the handover decision-making stage.

B. Tuning failure or "fake signals"

Tuning failure or "fake signals" refers to the situation where the DVB-H terminal makes supposedly the right handover to the target cell but actually handed over to another cell, which causes service interruption resulting from tuning failure. Handover in DVB-H utilises the PSI/SI tables within its received transport streams and information acquired from the TPS bits. The PSI/SI tables provide information to enable automatic configuration of the receiver to demultiplex and decode the various streams of programs within the multiplexed transport stream. In PSI/SI tables, there are different descriptors containing the signalling information for DVB-H. The information provided by the different descriptors is shown in Table 1.1 of Chapter 1. The terrestrial_delivery_system_descriptor and the frequency_list_descriptor in conjunction with the service_list_descriptor are the main parameters that are used in the simplest handover method introduced for the stationary and portable reception of DVB-T. Normally when a DVB-T terminal performs a handover, it will try to match the frequency of the strongest signal with the service id in its service_list_descriptor. If they match, it will perform the handover. However, if the terminal only uses these three parameters to perform handover tuning failure may result because these three descriptors are not enough to provide the match between exactly one service and one frequency.

The cell identification information, i.e. cell_id, is also signalled within the TPS bits of each received signal, which is critical for the receiver to discover the correct service. In other words, a "fake signal" is a signal that has the same frequency and cell_id as the targeted signal but which actually is from a different network and hence it is very unlikely that the receiver is able to receive currently consumed IP streams from it. Such a situation may occur for example when a cell of another network is using the same cell_id and frequency as the cell that the receiver aims to hand over to.

Tuning failure or "fake signals" is illustrated in Fig. 2.5. In Fig. 2.5 the two different DVB core networks are connected based on the two network operators agreement if they are operated by two different network operators.

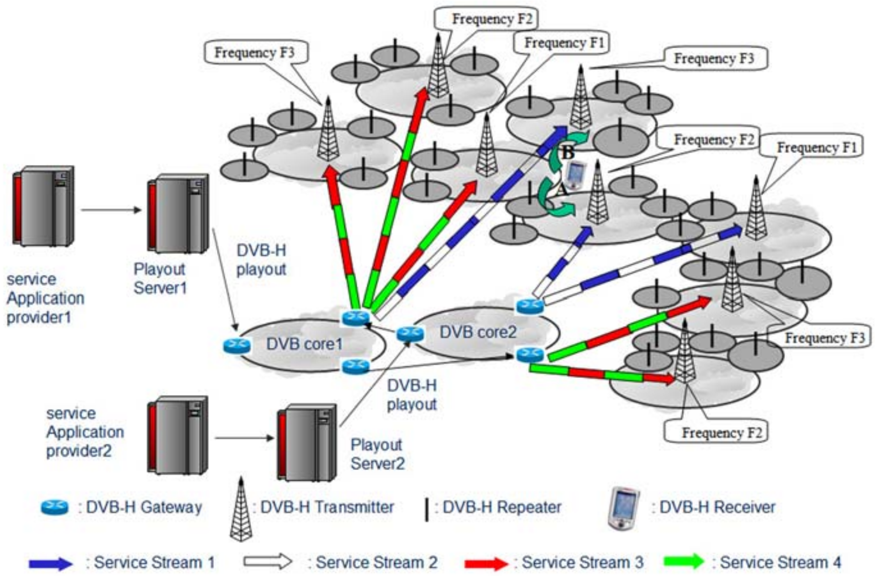

Fig. 2.5. Tuning Failure or Fake Signals

When the terminal moves from one cell to another as in case A shown in Fig. 2.5, it will detect a sufficient signal strength to trigger the handover process from the signals of frequency F2. As frequency F2 is matched with the desired service, the DVB-H terminal will perform handover from frequency F1 to frequency F2. However, after the terminal has handed over to F2, the user using the terminal will encounter a service interruption that is defined as tuning failure from the user's point of view. In case B, shown in Fig. 2.5, the DVB-H terminal will detect sufficient signal strength to trigger handover process from the signals of frequency F3. As frequency F3 is matched with the service the terminal is supposed to receive, the DVB-H terminal will perform handover from frequency F1 to frequency F3. Only after handing over to F3 does the user of the DVB-H terminal realize that there is a tuning failure. The difference between case A and case B is that case A happens when the terminal tries to synchronize with a frequency from another DVB core network where there are at least two different services using the same frequency. However, case B happens when the terminal tries to synchronize with the frequency from the same DVB core network where there are at least two different services using the same frequency. The two different services can be received on the same frequency because the two same frequencies in the network are far enough away from each other so that they do not interfere with each other even if they provide two different services. The signals causing tuning failure are also called "fake signals".

The tuning failure or "fake signals" described above can be avoided by appropriate network design and co-operation between network operators.

C. Power Consumption

In addition to the above-mentioned two main possible problems in the handover process of DVB-H, power consumption is the most important concern. Power consumption has always been a critical challenge for mobile handheld terminals [5, 6]. In fact, reducing power consumption is the reason why the DVB-H standard was developed [94, 110]. Although the introduction of time slicing has reduced the power consumption of DVB-H to a considerable extent compared with that of DVB-T, frequent handovers in DVB-H need more signal measurements which consume battery power. Even frequent handover measurements which may not necessarily result in handover will also consume battery power. Therefore, the handover algorithm in DVB-H should be fully exploited to further reduce the power consumption of the terminal in different stages and to avoid unnecessary power consumption as much as possible when handover is present.

D. Packet Loss

DVB-H is a unidirectional broadcasting network. If some packets are lost during the handover process there will be no retransmission of the lost packets. Packet loss will most probably happen when the terminal tries to synchronize to the target frequency and transport stream in the handover process. Delay and jitter are very common in the IP networks that are the service-feeding networks of DVB-H. Because of unidirectional nature of DVB-H no retransmission is possible except another uplink channel is utilized (e.g. UMTS). Since even a single lost packet will have a disastrous effect for some IP Datacast services in DVB-H (e.g. file downloading), strict synchronization techniques must be used in the synchronization of the time sliced services of DVB-H. Basically, packet loss is a fundamental issue in DVB-H that needs to be solved in any practical handover scheme for DVB-H. Further discussion of this issue can be found in [105, 113].

2.3 Designing a Better Handover Algorithm for DVB-H

The handover in DVB-H networks is the subject of on-going research and different approaches for designing handover algorithms by utilising mechanisms defined in [67, 68, 93] are developed all the time. In this section, some key points are presented as criteria for designing an efficient handover algorithm in DVB-H networks.

A. Handover Decision-making Stage

One of the key aspects in designing an efficient handover algorithm for DVB-H is to exploit the possibilities of reducing battery power consumption. The handover decision-making stage is the handover phase where the battery power consumption reduction can be fully exploited. The main objective in the handover decision-making stage is to try to predict the handover moment to reduce the number of off burst time intervals that are used for handover measurement.

One thing need to be noted is that most of the power consumption in the DVB-H service consumption cycle comes from the loading and playing of the media players when audio and video are involved. Although the front-end radio reception consumes less power compared with the media playing, it still makes difference regarding to the overall battery power consumption. Thus it should be considered in the handover design.

B. Complexity and Compatibility

The design of a handover algorithm for DVB-H should not conflict with the already consolidated DVB-H standards and the complexity of the handover algorithm should be fully exploited to ease the difficulty imposed on the receiver design.

C. Utilization of Additional Signalling Information

Additional signalling information should always be fully exploited by the handover algorithm. Handover in dedicated DVB-H networks has the characteristic of being passive where only the unidirectional transmission from the network to the terminal is possible. If additional signalling information is available, it should be used to help the handover process. Take the converged terminal as an example; converged DVB-H and GPRS/UMTS terminals have the advantage of having an interactive uplink channel. In this case, the uplink channel can be utilized to aid the handover process and this UMTS aided handover is a kind of active handover. The network parameters transmitted from transmitters and repeaters can also be fully utilized by the passive DVB-H receivers to aid the handover process.

D. Additional Equipment Cost

DVB-H terminals should be affordable for consumers. An additional attachment such as a GPS receiver can improve handover efficiency by predicting and checking the right handover moment. However, such an additional attachment will also increase the terminal price. From the economical aspect, the DVB-H handover algorithms should focus on utilizing existed signalling information that is available in the DVB-H standard to avoid the extra cost of introducing new network equipment (such as expensive repeaters) or terminal attachments (such as GPS receivers) if these extra equipments are used for handover purposes only.

In addition, the handover challenges presented in section 2.2.2 should be carefully considered when a handover algorithm is designed. The challenges such as the Ping Pong effect, "fake signals" and power consumption are sometimes related each other. For example, because more Ping Pong effect means more power consumption, when the Ping Pong effect is addressed, the power consumption is usually reduced as well.

Different handover algorithms have different characteristics. It is sometimes difficult for one algorithm to be used for all situations, for example, a handover algorithm utilizing UMTS interaction channels will not work when the UMTS network does not exist. While the above-presented evaluation criteria should be considered in designing an efficient handover algorithm for DVB-H, the individual application situation must also be taken into account. Designing an efficient algorithm usually implies a trade-off between power consumption, signalling information and additional equipment cost under the condition that the complexity and compatibility problems are considered.

Problems

2.1. What is IPDC?

2.2. What benefits does IPDC bring to DVB-H?

2.3. In which kind of DVB-H networks is handover required?

2.4. What are physical handover and service handover in DVB-H?

2.5. What are the different handover stages in DVB-H?

2.6. What are the handover challenges in DVB-H?

2.7. What are the issues that we should consider in order to design a better handover algorithm in DVB-H?

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