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Digital Switch-Over:
tackling in-home distribution

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Abstract

While the launch of Freeview has provided consumers with a wholly free-to-air digital platform, it is currently unclear whether digital terrestrial television in the UK will provide the coverage to 'portable' television sets currently offered by analogue terrestrial. Before digital switch-over can proceed, reception using a set-top antenna must be addressed. Wireless in-home distribution seems a likely candidate for serving portable televisions whereby digital television signals are re-broadcast in-home, enabling additional television sets to continue to source signals without additional wiring. Possible solutions based on peer-to-peer and networked architecture are explored.

Additional key words: Wireless local area networks, digital video sender, Ultrawideband

Summary

In carrying out an investigation into what technologies are available to carry out in-home distribution of digital television, the following were discovered:

- The Digital Television Group are currently developing a digital video sender which transposes a single DVB-T multiplex up to 5.8 GHz. The system is intended to be used in conjunction with a standard digital terrestrial set-top box at the receiving end. A control channel allows for communication between the receiver and transmitter in order for the transmitter to select the desired multiplex.
- Wireless networking may provide a platform on which digital television video may be distributed. Current standards employed for data communication, such as IEEE 802.11x, do not support high quality video due to insufficient bandwidth and lack of Quality of Service support.
- Future wireless networking technology looks encouraging, with a number of manufacturers developing rivals to IEEE 802.11x. Nothing has yet been manufactured to exploit the suggested capabilities of Magis Air5, ViXS and HiperLAN2.
- Ultrawideband (UWB) systems may provide an alternative to current wireless technologies, offering very high data rates and an operating range which could serve a home. UWB transmission spreads data over a very wide frequency range and therefore, if it is to be licensed in the UK, strict limits on emissions must be (carefully) defined and approved by the Radiocommunications Agency.

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1 Introduction

In September 1999, the Government set three criteria to be achieved before analogue terrestrial television can be switched off, dubbed Availability, Accessibility and Affordability:

- Availability: everyone who currently receives the main public service broadcast channels in analogue form must be able to receive them digitally
- Accessibility: 95% of consumers must have access to digital equipment
- Affordability: switching to digital should be an affordable option for the vast majority of people [1]

Taken together, the three main digital television platforms come very close to reaching 99.4% of the UK population, the coverage often quoted as being provided by analogue terrestrial broadcasts. With all five free-to-air services available across all three digital platforms, the Availability test seems to have already been met. Accessibility concerns the take up of digital television services, which currently lies around 44% of households. Affordability has become less of an issue since the launch of digital services, at which time all three platforms were marketed as pay-TV offerings. The collapse of ITV Digital and the subsequent launch of the entirely free-to-air Freeview has resulted in competing products, sold without subsidy from operators, pushing prices down.

The three digital television platforms do not lend themselves well to providing signals to homes with multiple television sets currently using set-top antennas for reception. Predominantly, multi-channel access is confined to televisions with their own set-top box fed from an external antenna, dish or cable. Before digital switch-over can become a reality, reception for so-called second and third television sets (all additional sets and VCRs) must be addressed.

This document outlines the current state-of-the-art with respect to wireless in-home distribution of high quality video and how this may impact on 'portable' reception of digital television (i.e. without requiring a connection to a rooftop aerial for DTT or a satellite or cable feed). Arguments are raised as to why this issue is of such importance before an overview of each technology is presented. This document then goes further into how television viewing may change in the future with the emergence of new technology.

2 Background

2.1 Digital television penetration

The current (July 2003) figure for penetration of digital television is 43.9% of households or around 10.2 million homes [2]. Digital terrestrial television (DTT) accounts for 1.6 million households, digital cable 2.1 million and digital satellite 6.4 million. The percentage of multi-channel homes (those receiving more television services than available through terrestrial analogue broadcasting) is 48.6%. The difference of around 1.2 million households relates to analogue cable subscribers, but these services are expected to be converted to digital in the next few years [3].

These figures relate to households and not individual television sets and VCRs. The demise of ITV Digital left around 1 million adapters in the hands of former subscribers, and these adapters may now be used to receive free-to-air services broadcast under the name Freeview. In some cases, former ITV Digital subscribers have retained their boxes as a 'second' set adapter while subscribing to an alternative (satellite or cable) pay-TV platform for their main television set.

The recent ITC Household Technology Survey [4] discovered there are on average 2.25 television sets and 1.56 VCRs per household. Together with the fact that the main living room only accommodates 45% of television sets, digital access for additional televisions must be addressed. The survey also discovered that 28% of multi-channel access already occurs outside the living room. Households with good DTT reception could provide digital access to all televisions and VCRs provided each is connected to a DTT adapter, sourcing reception from the rooftop aerial. Unfortunately, the survey also discovered use of rooftop aerials is in decline, with more than half of all television sets being fed by other means (although cable and satellite access will account for most of this). Around 35% of all second television sets use a set-top aerial and it is highly unlikely that such an arrangement will always be satisfactory for receiving DTT.

2.2 Providing reception for additional television sets

As mentioned above, taken together, it is likely that, after switch-over, the three digital television platforms will satisfy the Government's requirement for availability of digital services. By itself, digital satellite broadcasting achieves coverage of about 98% of homes[1] [3] yet in practice, planning permission or the need for landlord approval reduces the number of households who can receive it. Cable is currently available to around 50% of households, but only half of them are able to subscribe to digital services [3]. Digital terrestrial coverage is currently around 73% of households for core coverage[2] with around 51% likely to require an aerial upgrade[3]. It is estimated that maximum DTT coverage will be around 80% of the population of which 25% will require an aerial upgrade [3]. In general, availability will be made up of a combination of the three platforms, as each alone cannot satisfy the criterion. It is unlikely that homes with pay-TV access will extend subscriptions for all television sets. Current deals with satellite and cable operators offer additional adapters for an extra £15 per month on top of the cost of installation[4]. It is more likely that the current model will continue post switch-over whereby additional television sets predominantly provide only free-to-air services. Since the demise of ITV Digital, DTT has become a wholly free-to-air service and hence more akin to analogue terrestrial. It is likely that DTT will be adopted as the means of reception for the vast majority of additional television sets.

However, digital coverage is currently made up of a combination of all three platforms and will continue to be post switch-over. Households not served by DTT are forced to use either satellite or cable for their digital television reception and hence cannot use DTT for additional sets. The BBC's decision to broadcast 'in the clear' on satellite means consumers can watch BBC services without a viewing card on digital satellite and may pave the way for free-to-air satellite receivers offering similar services to Freeview[5]. This is another step forward but in order for additional televisions to be covered post switch-over, hardware must be available for each digital platform so that free-to-air services can be received without subscription.

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[1] 100% footprint reduced by certain locations not allowing line-of-sight link to satellites

[2] Core coverage represents households which can receive all six multiplexes

[3] Rooftop aerials generally only provide reception for a limited 'group' of channels to reduce cost. DTT was planned around the current analogue services and thus in some areas, some multiplexes are 'out of group' and a wideband aerial is required

[4] Sky currently charge £99 for an additional Digibox plus installation plus £15 per month per subscription. The same applies for ntl and Telewest but both cable operators offer an additional adapter free of charge

[5] Digital satellite set-top boxes accessing free-to-air services are available but are not being marketed to consumers. Fusion Digital Technology, a company set up by Beko Elektronik, are about to release low-cost DTT and D-Sat boxes and such a step forward may force other manufacturers to follow suit

Satellite subscribers have already shown an interest in watching digital television in other rooms in the house. Sky incorporated a clever feature in their Digibox: all Digiboxes feature a second RF output, which can be used to pipe the same video to another television. This second RF output also accepts input of remote control commands on the same cable. A small device called tvLink, which retails for around £10, receives remote control commands and sends them back along the RF cable to the Sky Digibox. In this way, a second television can show the same Sky channel as the main television but therefore is not independent. More television sets receive digital services using Sky's tvLink device than through DTT [4] so there is a market for such a low-price device allowing viewers to watch and control digital television from another room, e.g. the bedroom at night. However, this is not a fully independent solution.

It is clear that the established analogue television network is hard to replace, in terms of coverage at least, even with a combination of services. While all three platforms offer vastly improved choice and additional services, we cannot move beyond analogue until these services can received by all *televisions and VCRs* currently receiving analogue.

3 In-home distribution of digital television

3.1 From analogue to digital

In-home distribution of digital television concerns ensuring all television sets and recording devices (VCRs or PVRs) receive digital pictures. This may sound like an abstract model but it is already employed in 40% of homes [4] containing second and third television sets where analogue reception is achieved through multiple connections to the rooftop aerial. A high-level look at in-home television distribution is required because, upon moving into a digital domain, there is more than one way in which it can be achieved. This abstract model is illustrated in Figure 1.

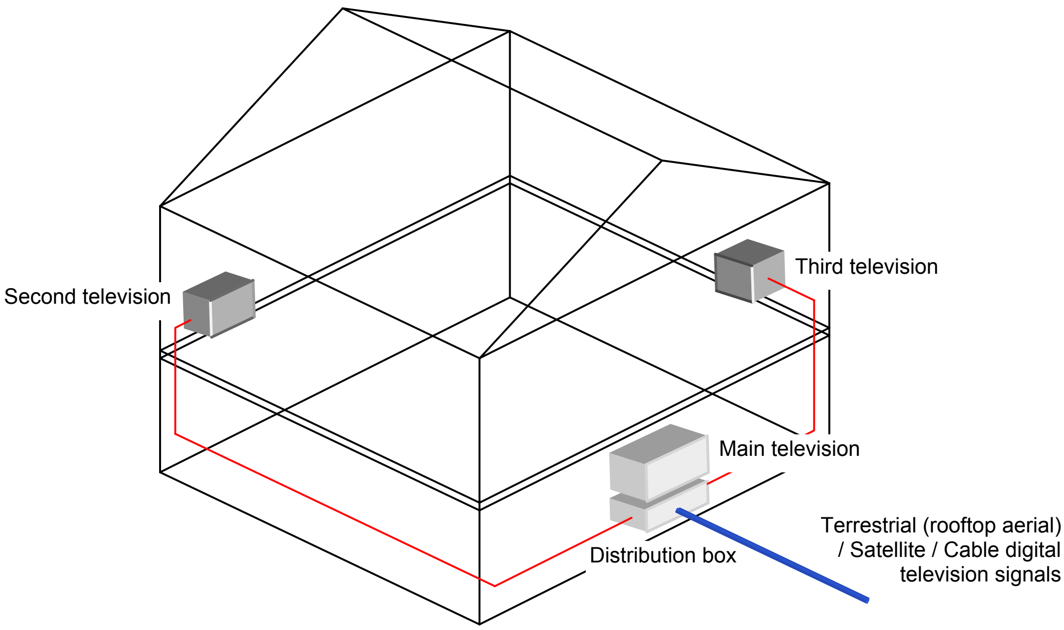

Figure 1. Abstract diagram of in-home distribution of digital television

Digital television is broadcast to the home and received using one of the three platforms. In much the same way that amplifiers and splitters are required for multiple connections to a rooftop aerial, a device with a high quality source of digital television signals (i.e. connected to rooftop aerial, cable or satellite) is used to distribute the pictures to other devices within the home.

There are various ways in which this may be achieved using dedicated point-to-point connections or via an in-home network, used by other devices for sharing media.

3.2 Wireless technology

In order for digital television to be accepted by those who will only change upon switch-over, the disadvantages it brings must be few and minor. Currently, those who have bought digital have done so out of choice and have chosen the best platform for their situation. As switch-over approaches, digital television penetration will increase due to necessity and thus situations currently not suitable for digital will need to be addressed, such as second television sets using set-top aerials. To preserve their ‘portability’ (i.e. so that they do not require being cabled to a rooftop aerial, satellite dish or cable link), it is highly likely that they will continue to need to achieve wireless reception. Set-top reception of DTT is likely to be unachievable for those who currently put up with poor analogue reception and therefore wireless distribution of digital pictures (taken from a rooftop aerial, satellite or cable link) must be available in-home.

High-speed wireless communication devices predominantly transmit between 2 and 6 GHz and generally use the licence-free ISM (Industrial, Scientific and Medical) bands. The ISM bands are located at 2.4 - 2.5 GHz and 5.725 - 5.875 GHz as shown in Figure 2. The diagram illustrates frequency regions used by possible solutions for in-home distribution of digital television: the wireless LAN (local area network) technologies IEEE 802.11 a, b and g and the Digital Television Group’s digital video sender (DVS) device, which are discussed in further detail in Sections 4 and 5.

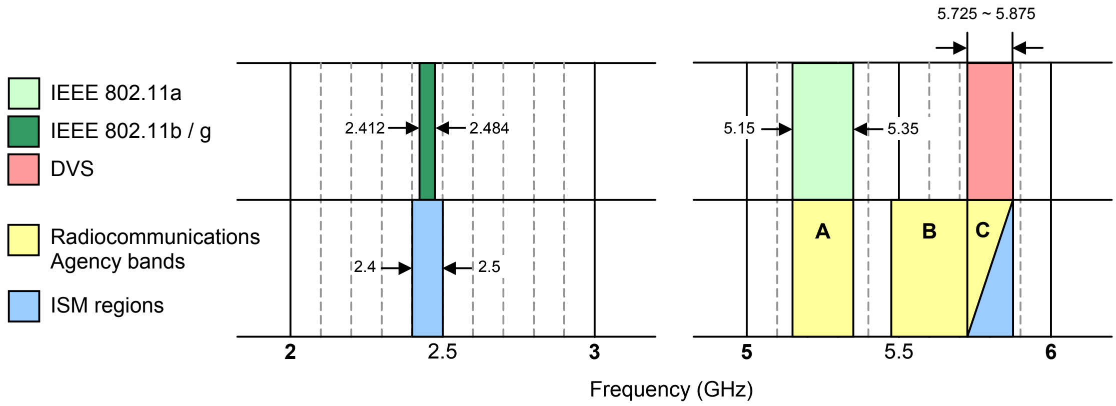

Figure 2. Frequency allocation for ISM bands and relevant wireless technology (UK)

Devices using the ISM bands (which are also located at other frequencies outside this region of spectrum) must still adhere to the Radio Regulations [5], which specify the nature of devices (mobile/fixed, internal/external, etc.) and their maximum transmitting power. Table 1 lists basic characteristics for devices using various frequency bands.

	2.4 ~ 2.5 GHz (ISM band)		5.15 ~ 5.35 GHz (Band A)	5.725 ~ 5.875 GHz (Band C, ISM band)
Use	Non-specific short range (indoor) devices	Radio Local Area Network		Non-specific short range (indoor) devices
Maximum power	10 mW EIRP	100 mW EIRP	200 mW EIRP	25 mW EIRP
Notes	Video app's allowed ≤ 20 MHz BW		Indoor use only Devices must be nomadic	

Table 1. Outline specification for devices within frequency bands[6]

The IEEE 802.11a standard does not reside within an ISM band but does not require a licence due to restrictions on transmitting power. Due to the fact IEEE 802.11a does not share the same frequency band as ISM devices, it is relatively interference-free and uses a greater bandwidth and thus higher data rates compared with IEEE 802.11b.

Each band is separated into a number of channels, for example, the DVS project assigns 18 channels of 8.33 MHz width within the 150 MHz window centred at 5.8 GHz, each allowing carriage of a single UHF television channel of 8 MHz bandwidth. This allows a point-to-point link to be established on whichever channel is experiencing the least interference. It also opens the possibility for a number of similar devices to use the same frequency band without interfering with each other.

3.3 Take up of new technology

A joint project between Marketing, Communications & Audiences, Strategy and Distribution, the recent BBC Digital Homes project [6] returned some encouraging results about the take up of new technology. In general, technology penetration follows a trend as shown in Figure 3. Initially take up is slow, gradually picks up speed, then slows and saturates at a point somewhere below 100%.

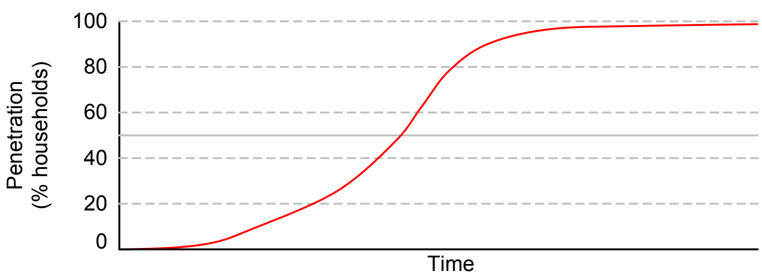

Figure 3. General trend for penetration of new technology [6]

Young people push the take up of new technology with devices such as DVD players and Sony's PlayStation2 being the fastest selling consumer electronics products after they were launched. This has not been at the expense of television and radio and since its launch in 2002, Freeview has become the fastest selling consumer electronics product in the UK with over 7% penetration within a year of launch and almost 2 million adapters sold [7]. Even with the emergence of new technology aimed at young people, such as high-speed Internet access and games consoles, television still dominates what is found in homes. The BBC Digital Homes project found that 92% of living rooms

[6] Radio Regulations Annex B

contain a television set and televisions can also be found in 62% of childrens' bedrooms and 52% of adults' bedrooms.

3.4 Possible solutions

As mentioned in Section 3.1, there are two mechanisms by which additional television sets could achieve digital reception. A television far from where digital signals enter the house could either be fed by a wireless point-to-point link or be part of a network which feeds all televisions in-home from a single point of entry. The following sections detail developments in each.

4 Digital video sender device

4.1 Analogue video sender devices

Wireless video sender devices are nothing new. The European market alone was around 1 million units in total in 2002 [8]. Video senders were first produced to allow consumers to send video signals from one room to another without the use of cables. In recent years, video senders have gained greater functionality such as the ability to switch input and send remote control commands back to the input source. Prices have also fallen with increased demand and competition and a sophisticated device now costs under £100.

A typical analogue video sender operation is illustrated in Figure 4. The video is transmitted at 2.4 GHz using FM while remote control commands are converted to signals at 433 MHz. The transmitting device relays remote commands to the input device(s) through infrared 'eyes'.

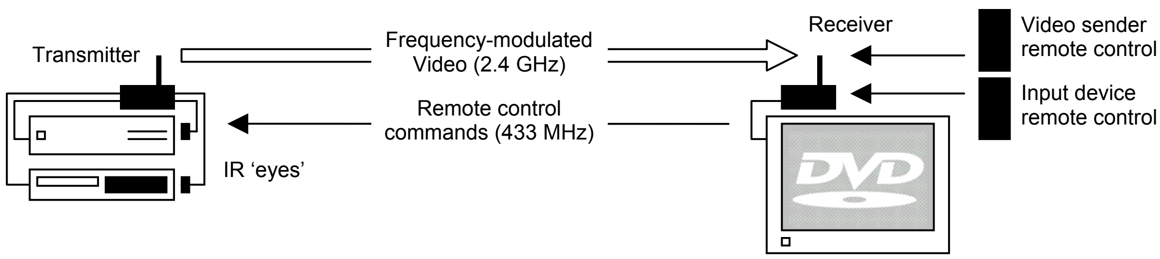

Figure 4. Analogue video sender operation

If video from a standard digital set top box (STB) was input to an analogue video sender, a single channel of digital television could be distributed to another television in the home. This is a perfectly legitimate method for doing so but does not provide the most efficient answer. Such an installation would mean the video being down-converted from UHF and decoded before being re-coded and up-converted to 2.4 GHz. While staying in the analogue domain, such devices do not benefit from digital transmission which provides greater resilience against interference (a perfect digital picture may be reconstructed in the presence of noise) and increased picture quality due to component transmission.

4.2 Digital video sender

The Digital Television Group (DTG) Wireless Home Networking group (DTG-WHN) is currently carrying out a feasibility study into a digital video sender (DVS) device. The DVS project is primarily concerned with distributing DTT throughout the home. Extensions to the basic specification exist which could permit its use with other digital television platforms.

In essence the DVS simply up-converts a single UHF channel but retains the MPEG-2 transport stream rather than transmitting a single analogue video channel. The study has produced a basic specification which is illustrated in Figure 5.

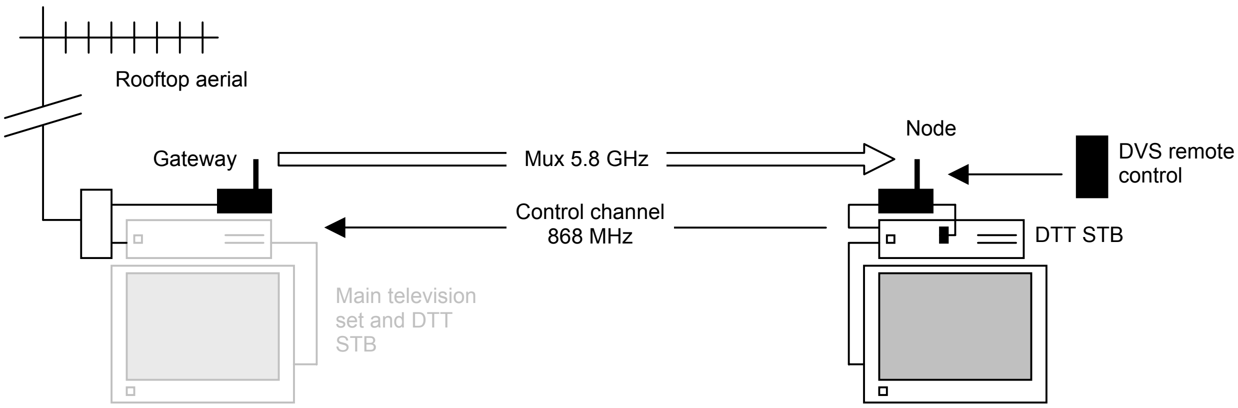

Figure 5. Digital video sender (DVS) operation

The DVB-T multiplex containing the desired channel is selected and up-converted to Band C (5.725 GHz - 5.875 GHz) in the transmitter, or Gateway, device. The receiver, or Node, device down-converts back to UHF to allow a standard DTT STB to be used. In order for the correct multiplex to be selected when the user changes channel, the DVS Node controls the STB. The user interacts with the DVS Gateway rather than the STB. A control channel is required in order for the Node to inform the Gateway which UHF channel to select, so that the correct multiplex containing the desired service is transmitted to the Node. This communication channel is also used on initiation of a link so that the best channel in Band C (in terms of interference and signal strength) can be selected.

4.3 Technology and operation

As outlined above, the Gateway contains a UHF tuner that selects the desired multiplex to be up-converted to Band C. Band C is split up into 18 x 8.33 MHz wide channels, each allowing room for an 8 MHz UK television channel. On initiation of a transmission, the Gateway and Node devices take a short time to decide which channel is experiencing the least interference, with communication made using the control channel. The control channel is likely to occupy a region of spectrum around 868 MHz or 2.4 GHz (although no final decision has yet been made) and support a data rate of around 20 kb/s with a maximum duty cycle of 10%. It is likely that devices will include dynamic frequency selection (DFS) in order for the optimum channel to be selected throughout an established link.

The International Telecommunications Union (ITU) specifies such devices can operate in Band C licence-free as long as the transmitted power does not exceed 25 mW. It is possible that larger homes will require some form of repeater. The Node includes two receivers, to exploit diversity reception, improving resilience to varying multipath interference caused by people moving around.

4.4 Device profiles

The description above details the simplest form of DVS the DTG-WHN group is investigating. As with other such communication technology, solutions can be made scalable, i.e. more complex profiles of the device exist, extending its capabilities. There are in fact 5 profiles the project details:

1. DTT only, ideally without re-encoding
2. Any digital source, without conditional access (CA)[7]
3. Any analogue or digital source, without CA
4. Multiple simultaneous sources, without CA
5. Digital pay-TV with end-to-end CA

Profile 2 requires a DVB-T encoder in the Gateway, allowing a baseband MPEG-2 digital source to be selected as opposed to off-air DTT. Profile 3 extends this to provide an MPEG-2 encoder before the DVB-T encoder so that a baseband analogue source can be selected alongside off-air DTT. Profile 4 combines profiles 2 and 3, accepting both an analogue and a digital input and allowing the user to therefore chose one of three inputs. Profile 5 is an extension of profile 4 in which digital rights management (DRM) is taken into consideration, supporting end-to-end CA for pay-TV services.

It is highly likely that all profiles above 1 will not find wide take up, especially when considering the costs involved in manufacturing MPEG-2, DVB-T and T-Mux (required for multiplexing services together into a single transport stream) encoders for the home market. Profile 1 offers all that is needed to serve additional television sets with digital television sourced from DTT.

4.5 Testing and further development

Testing of the profile 1 device will begin within the next 6 months (early 2004) at BBC Research & Development at Kingswood Warren. Preliminary tests have been ‘very encouraging’. While the forward channel is already defined (as it is simply an up-converted transport stream), it is anticipated that defining the control channel will take time.

4.6 Critique

While profile 1 is the most likely to find a market, it only provides a solution to those who can achieve good DTT reception from a rooftop aerial. For those who use satellite or cable to receive digital television, a higher profile would have to be used. Video senders are clearly popular devices but are seen as providing additional functionality over that which portable analogue television sets provide. A great deal depends on how users interact with a DVS, dictating whether such devices will become popular. However, market acceptance, penetration and popularity are not one and the same. When digital switch-over approaches, acceptance, and therefore take-up, will depend on flexibility and price. Consumers will have to adopt new ways in which they interact with their television sets but a DVS seems like an unintrusive device which can be made relatively cheaply.

5 Wireless in-home entertainment networks

5.1 Overview

5.1.1 Convergence of technology

The DVS project attempts to tackle the problem of digital reception for second and third television sets starting from a traditional television-orientated perspective. Digital broadcasting has created a new perspective, that of software as well as hardware providers. Set-top boxes (STBs) are gradually evolving to take advantage of new capabilities which digital broadcasting brings. Interactivity and a return path are finding uses in a growing number of programmes with viewers able to play games,

[7] Conditional Access (CA) refers to rights held on certain broadcast media, e.g. Pay-per-view films

choose alternative content and cast votes using the STB software. The convergence of computer capabilities with broadcasting is transforming the way users interact with their television sets and there has never been so much information available to them.

Widespread acceptance of technologies such as the Internet and MP3 audio files has brought the PC back to being more than just a word processor. PCs have found their way into around 54% of UK households, with around 45% of homes having Internet access. More and more consumer electronics (CE) devices are attempting to take advantage of new technology acceptance and exploit the PC's capabilities and those brought by connectivity, by including a network interface. Devices such as games consoles, portable and home music systems and digital cameras are available which offer additional features when used as part of a network or require the use of a PC. The home entertainment network is emerging.

Naturally, manufacturers are looking further into the future and as one article has put it, "All set-top-box and consumer electronics manufacturers have wireless home networking on their radars." [9] Inclusion of television in home networking has been made significantly easier with digital broadcasting. Just as MP3 audio simplifies moving music from one device to another, MPEG-2 video can be moved around a computer-orientated network without significant change. Issues concerning data rate and transmission quality of service remain (see below) but a home network may be exploited as a means by which additional television sets acquire a signal post switch-over.

5.1.2 Home network models

Through use in the business world, computer networks have developed to supply solutions for companies large and small. In the same way, a networked home can mean a number of different things. The most basic home network is simply a small-scale version of an office network, as shown in Figure 6.

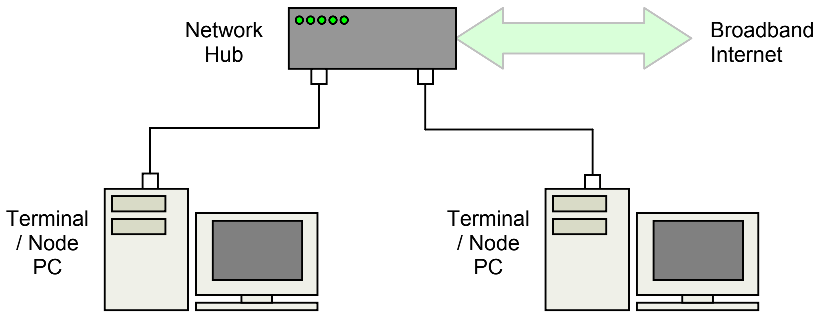

Figure 6. Basic home computer network

Networked PCs allow users to play multiplayer games, share photos, music and any other type of computer file. In a growing number of homes, multiple PCs share a broadband Internet connection through a modem/hub, also allowing the local PCs to talk to each other. However, this is not a home *entertainment* network.

A home entertainment network incorporates CE devices to give users greater access to all types of media. For example, digital photos can be shown on the living room television set in the form of a slideshow. While a PC may be a part of a home entertainment network, it is not at its core. Figure 7 illustrates a home entertainment network.

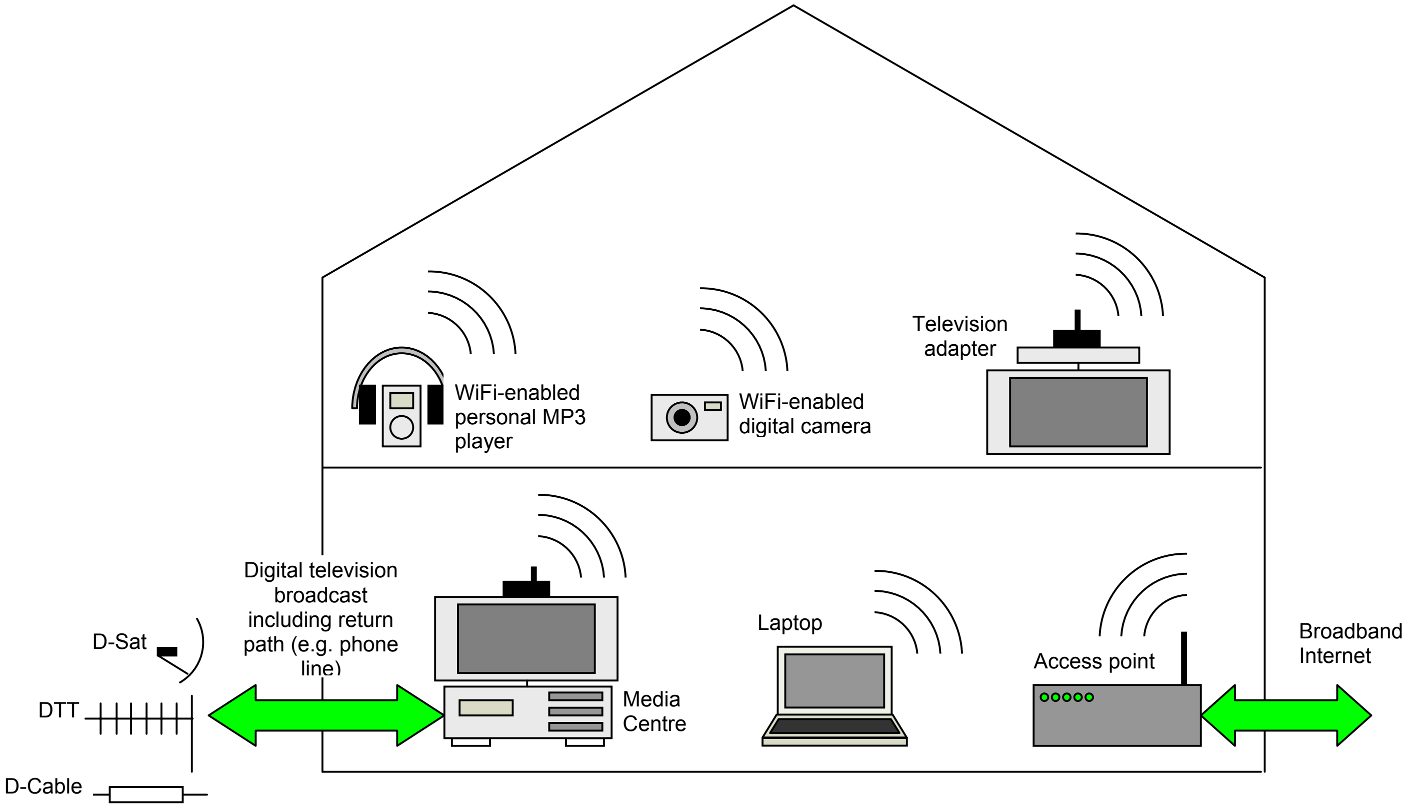

Figure 7. Wireless in-home entertainment network

The illustration suggests that connections between devices in a home entertainment network are wireless. Apart from this important level of flexibility, such a set-up is almost possible today. Manufacturers of STBs are keeping a close eye on in-home networking developments, as an enhanced STB is likely to form the hub of such an entertainment network. As mentioned above, digital television has brought with it more information and a format that is friendly to network distribution but with it, developments in STB technology have introduced personal video recorders (PVRs) which allow users to record a series of programmes and even pause live television. With a few enhancements, the digital STB/ PVR combo could provide television services as well as pre-recorded programmes to all the television sets in the home. Manufacturers have dubbed such devices ‘Media Centres’, as they will provide more than one form of audio-visual entertainment with the likely inclusion of DVD, CD and MP3 playback, and Internet access.

With respect to the title of this Tech Note, in-home entertainment networks may be exploited as a mechanism by which second and third televisions acquire digital pictures post switch-over. The key to this, especially when regarding portable sets, is wireless technology.

5.2 IEEE 802.11

Dubbed ‘wireless Ethernet’, IEEE 802.11 is a standard for high-speed wireless data communications and has been adopted as the standard for WLANs (wireless local area networks). Many flavours of IEEE 802.11 are now available, as extensions have been added as needs have changed.

All IEEE 802.11 standards used today incorporate the same basic medium access control (MAC) layer. The MAC layer regulates spectrum use and informs each node when to transmit and when to receive. With a multi-node wireless network, only one terminal may be transmitting at any one time in order to avoid ‘collisions’ of data streams. This is achieved using Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA) whereby a sending terminal tests for a clear channel before beginning transmission. The receiving terminal sends explicit acknowledgements (ACKs) in response to each packet successfully received. If an ACK is not received, a collision is assumed to have occurred and the packet is re-transmitted after a random length of time. This mechanism is less efficient than wired Ethernet and hence places an overhead, reducing system throughput. The various versions of IEEE 802.11 use this mechanism for medium access but vary in the way they modulate the carrier to produce the transmitted signal.

The original IEEE 802.11 standard uses Direct Sequence Spread Spectrum (DSSS) or Frequency Hopping Spread Spectrum (FHSS) in order to spread the spectrum of the data signal to improve its resilience to interference. DSSS is a process whereby the original data signal is combined with a higher data rate bit sequence or chipping code, spreading the spectrum of the data signal over a wide frequency range. This causes redundancy (more bits are sent for each useful bit of data) but increases resilience to interference as multiple errors can be removed in the receiver. FHSS refers to transmitting the original narrowband data stream at a different frequency. The signal 'hops' from one frequency to another in a pseudo-random sequence known to both transmitter and receiver. This has the effect of spreading the spectrum of the transmitted signal in the frequency domain and increases resilience to interference as a single frequency is used for a very small amount of time.

5.2.1 IEEE 802.11b

In saying IEEE 802.11 has been adopted as the standard for wireless LANs, more specifically, the 1999 IEEE 802.11b variant has. Working in the 2.45 GHz ISM band, IEEE 802.11b uses 13 channels (in Europe) of 5 MHz width with centre frequencies from 2.412 GHz to 2.472 GHz. A single IEEE 802.11b signal occupies about 22 MHz bandwidth and provides a maximum *transmitted* data rate of 11 Mb/s. With transmitted signals occupying more bandwidth than a single channel, adjacent channels can not be used simultaneously. DSSS is used as the method for improving link resilience.

Usable data rates for IEEE 802.11b are somewhat lower than the quoted maximum and the maximum net throughput is around 4.5 Mb/s. The reason for this lies in the use of DSSS, which throws away a large fraction of available throughput, CSMA/CA and additional error correction.

IEEE 802.11b has become widely established as the standard for WLANs and Wi-Fi hopspots, which are increasingly being found in cafes and airport lounges[8]. Sharing 4.5 Mb/s is enough bandwidth for data applications such as email but is not sufficient when users want rich multimedia web browsing.

IEEE 802.11b clearly does not possess the available throughput for multiple streams of digital television, especially as part of a network supporting other types of traffic. Having said that, a wireless television system has already been developed using IEEE 802.11b as its medium. Toshiba's FACE Wireless system comprises an encoder / transmitter and a LCD display incorporating a receiver / decoder. The encoder takes analogue RGB as its input and encodes the video to MPEG-2 before embedding it into an IEEE 802.11b transport stream. The system is more analogous to a digital video sender with the receiver being part of the display.

5.2.2 IEEE 802.11a

Using the IEEE 802.11 MAC layer, IEEE 802.11a specifies a wireless protocol at 5 GHz using OFDM in its physical layer. Working at 5 GHz means transmissions experience less interference than is found at 2.45 GHz caused by other short-range devices (SRDs) in the ISM band. IEEE 802.11a is currently allocated spectrum in Band A, 5.15 - 5.35 GHz, and uses 8 centre frequencies

[8] 456,000 people will use Wi-Fi hot spots this year according to a study by Gartner (BBC Flash Report, w/e 17/08/03)

in Europe. The maximum transmitted data rate is 54 Mb/s but due to system overheads, the maximum net throughput is in the region of 21 Mb/s [10].

OFDM is a similar transmission mechanism to that used in DTT. By separating the transmitted signal into many slow symbol rate signals on separate carriers, and adding a guard interval to each symbol, multipath interference is reduced. IEEE 802.11a uses 52 sub-carriers each transmitting a data rate of around 300 kb/s. Combined with FEC (forward error correction) and an spread data stream (bits adjacent in time are not transmitted adjacent in frequency), the transmitted signal is robust to bursty interference.

IEEE 802.11a is not as widely established as IEEE 802.11b in the office but its higher data rate and reduced interference make it a likely candidate for home networking where traffic is more demanding.

5.2.3 IEEE 802.11g

The recently standardised IEEE 802.11g specifies WLAN transmission at 2.4 GHz, like IEEE 802.11b, but uses OFDM and supports a maximum transmission rate of 54 Mb/s like IEEE 802.11a. The maximum net throughput is likely to be similar to that of IEEE 802.11a, although this is yet to be confirmed. The real selling point of IEEE 802.11g is that access points (devices connecting wireless and wired networks) and mobile terminals (hardware in mobile devices) can be backward compatible, supporting both IEEE 802.11b and g standards. This capability allows Wi-Fi hotspots and WLANs to be upgraded gradually whilst continuing to support users who have IEEE 802.11b hardware.

5.3 Cost

Take up of IEEE 802.11b for business use has pushed the price of WLAN hardware down, benefiting the home consumer market. An IEEE 802.11b access point costs around £120 and a terminal adapter costs around £30. Whilst it is unlikely that home entertainment networks can be supported by IEEE 802.11b, the price of IEEE 802.11a is not that much greater. Sales figures for WLAN hardware are soaring with an increase from 22.5 million units in 2002 to a projected 41.3 million in 2003 [11]. This has caused dramatic effects on the price of IEEE 802.11b chipsets. In 2002 the average cost price was US$16 but it currently stands at around US$6 and is expected to fall to as low as US$4 by the end of the year according to one Taiwanese chip manufacturer. Such a dramatic decrease in chipset prices has caused revenues to decline even with sales figures soaring. An 84% increase in sales has yielded an 8% decline in revenue from US$368 million in 2002 to a projected US$340 million in 2003 [11].

IEEE 802.11g chipsets are already being influenced by dramatic sales with prices expected to be around US$9 by the end of the year, half their value of last year. The price of RF chips is maintaining a small amount of stability over hardware prices but, with a number of Taiwanese vendors interested in entering the market, the price of RF chips and hence WLAN chipsets may yet fall further.

	802.11a	802.11g	802.11b
Frequency range (Europe)	5.15 GHz – 5.35 GHz	2.412 GHz – 2.484 GHz	
Transmission system	OFDM		DSSS
Maximum output rate	54 Mb/s		11 Mb/s
Net throughput	Around 21 Mb/s	*Unknown*	Around 4.5 Mb/s

Table 2. Comparison of IEEE 802.11 wireless LAN standards

5.4 Quality of service

A home entertainment network will, by its very nature, need to support streaming of high quality video and audio along with other traffic such as email and web browsing. Each type of traffic has an associated Quality of Service (QoS) requirement, which is dictated by its resilience to errors, jitter and delay and its required bandwidth. Pure data traffic such as web browsing only requires a bursty channel (intermittent data rate) and copes well with delay but cannot stand errors. So long as the web page loads within a reasonable length of time and has no errors, the user is happy. High quality video however requires a high QoS guarantee on data rate, errors and jitter but can cope with a fixed delay. High quality video requires a large bandwidth (from around 4 Mb/s for a DVB MPEG-2 service) and cannot cope with jitter – we are very good at spotting lack of synchronisation between pictures and sound, especially for speech.

As mentioned above, IEEE 802.11 is considered to be wireless Ethernet and as such has been very successful in giving Internet surfers and emailers wireless access in coffee shops and airport lounges. Neither IEEE 802.11a or b or their new sibling g offer QoS guarantees for traffic as part of their standards and manufacturers must either wait for output from IEEE 802.11e, a task group currently working on enhancing the 802.11 MAC to include QoS support, or to provide proprietary solutions. Development of the 802.11 MAC is seen by many as an afterthought and they have stuck with proprietary solutions for QoS support, as is seen in Toshiba's FACE wireless television system outlined above. This is not a problem for single devices, but proprietary QoS support will cause incompatibility between products, and will not allow networks of equipment from different manufacturers to become reality.

5.5 Alternative technologies

The following technologies offer alternatives to exclusive use of IEEE 802.11 for wireless networking. These technologies may also support hybrid solutions for in-home digital television distribution.

5.5.1 Asynchronous Transfer Mode

A network protocol exists which establishes a QoS agreement for traffic before a transmission is established. This protocol is known as Asynchronous Transfer Mode or ATM. While ATM is not a wireless standard, a great deal can be learned from the mechanisms it employs in order to ensure traffic receives a reliable connection. At the heart of the QoS guarantee is asynchronous time division multiplexing (ATDM) which allows multiple asynchronous data streams to receive an appropriate level of service. Figure 8 illustrates ATDM in operation.

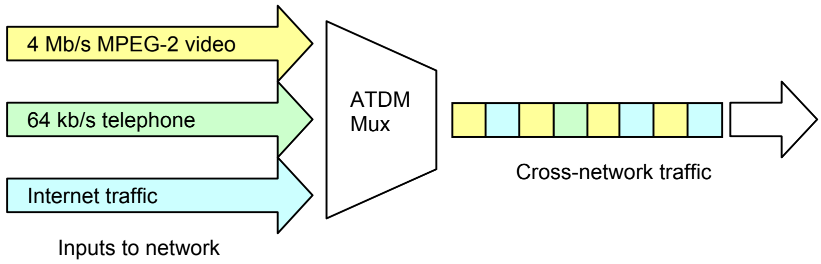

Figure 8. Asynchronous time division multiplexing

Over a network, various types of traffic can withstand different bandwidth, jitter and delay. An ATDM multiplexer ensures that cross-network bandwidth is occupied by the correct rate of data from each input source. Real-time streams such as video are given the highest priority while traffic such as Internet data is left with the residue of bandwidth, which fluctuates with time. The actual operation of an ATM multiplexer is more complicated and requires a buffer to store data from each stream as they arrive. The essence of ATM is that a QoS contract is drawn up for each data stream across the network, before it can begin. If a stream breaks this contract, supplying data at a higher rate for example, the stream data is not carried if the network is at capacity.

5.5.2 HiperLAN2

HiperLAN2 is a connection-orientated wireless communication technology much like IEEE 802.11a, transmitting in the 5 GHz ISM band. Each connection can be set a specific QoS in terms of bandwidth, delay, jitter, error rate, etc., or connections can be assigned a priority. The standard claims "The QoS support in combination with the high transmission rate facilitates the simultaneous transmission of many different types of data streams, e.g. video, voice and data." The 'high transmission rate' is quoted as 54 Mb/s, equal to the transmission rate of IEEE 802.11a, whether realistic throughput approaches this is unknown. The reason being that HiperLAN2 has quickly lost the support of manufacturers in favour of the IEEE 802.11 standards with proprietary QoS support, or future use of IEEE 802.11e.

5.5.3 Magis Air5

Magis Networks also claim to have developed a wireless chipset which supports QoS. The Air5 chipset has been demonstrated supporting a US-HDTV stream "as good as wire" as the Magis website purports. Air5 transmits in Band A (5.15 – 5.35 GHz) and is compatible with both IEEE 802.11a and HiperLAN2 physical layers but uses a reduced-complexity version of the HiperLAN2 MAC layer in order to meet the needs of the home networking market for both high quality application delivery and cost effectiveness [12]. The MAC layer employed by IEEE 802.11 uses CSMA/CA as detailed before which adds unnecessary protocol overhead and reduces the efficiency of communication.

Magis have outlined ten network scenarios which their product can support made up of HDTV, SDTV, DVD and data traffic. For purposes of carrying digital television, Magis suggest an Air5 network can support four SDTV streams with an additional 1 Mb/s data capacity. It is unclear how such a network performs with broadcast quality MPEG-2 video streams, but Magis claim a total data capacity of 48 Mb/s throughput with a maximum of seven QoS streams at any one time. This is dependent on a number of factors such as propagation distance and the only results to go on are those supplied by Magis themselves, but the specifications are encouraging.

5.5.4 Ultrawideband

Ultrawideband (UWB) signals are categorised as those having instantaneous bandwidth in excess of 25% of their centre frequency or those exhibiting an absolute bandwidth of 1.5 GHz or more [13]. In creating UWB signals, traditional carrier modulation is not used. Instead, the basic signal structure is made up of very narrow pulses, in the order of pico-seconds. Alone, such a regular pulse train results in a frequency spectrum containing regular spectral lines. One way in which data can be carried by such a system is by using pulse position modulation (PPM). PPM applies a small time shift to a number of pulses to represent logic 1 and no time shift to represent logic 0. To further flatten the power spectrum of the signal, a pseudo-random noise (PN) sequence is added to the time shift in order to randomise pulse position. This process is known as pulse dithering. When UWB is used to create a communication network, applying a unique PN sequence to each user's transmission allows multiple users to share the same spectrum and further flattens the system's power spectrum.

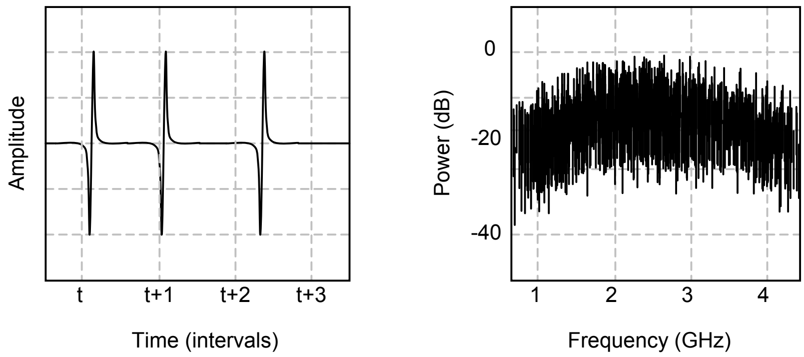

Figure 9. Pulse Position Modulation (PPM) with pulse dithering and the resulting power spectrum

What features of UWB systems make them a likely candidate for future high-speed wireless data communication? The main advantage lies in the power spectrum generated by UWB signals. While a wideband signal covering a large number of already cluttered frequency bands does not seem desirable, at low power, its spectrum, and hence its interference to other devices, is noise-like. Another possible advantage of UWB is that it may find worldwide spectrum use. Standards such as IEEE 802.11 operate in different frequency ranges in the US, Europe and Japan and so hardware must be made to cope with this or for use in a single region. Such universal standardisation could reduce costs, increase development and speed up time to market.

On 23rd July 2002, the Radiocommunications Agency sponsored a one-day colloquium on UWB technology. Manufacturers such as Sony and Philips and standards bodies such as the US Federal Communications Commission (FCC) presented suggestions for UWB applications. Sony are very interested in home entertainment networking and laid down a number of criteria they believe should be supported:

- 100 Mb/s desired data rate
- QoS support
- Scalability
- Hardware cost comparable to Bluetooth[9]
- Must live alongside 2.4 GHz and 5 GHz wireless technology

[9] Bluetooth technology allows wireless communication between devices such as mobile phones and handsfree headsets

Philips presented work carried out by the research group Ultrawaves, investigating high data rate wireless communications supporting high performance and low cost, i.e. for the home market. They have also been focussing on home entertainment networking and see wireless connectivity as the next necessary step forward, ending interconnection incompatibility. Possible applications are wireless projectors and DVD players and they suggest four MPEG-2 streams as a minimum capacity.

The colloquium concluded that UWB range was short, around 10m, with 30m being ideal. Transmitting power would be in the range 40 ~ 80 mW, rising to over 150 mW for high bit rates. Data rates of 100 Mb/s and above are the goal.

It is clear that UWB is not a tested technology and it is not known whether it will be able to impact on the home networking market until certain hurdles have been cleared. While low power noise-like interference may not pose a significant threat to short-range devices using the ISM bands, a number of UWB devices may emit significant power and hence cause interference. Implementation of UWB must also strictly limit emissions in restricted frequency bands. The FCC has granted preliminary approval for unlicensed[10] use of UWB in the US, placing strict limits for emissions as illustrated in Figure 10. It is unknown whether similar, or greater, restraints will be placed on devices used in Europe but this provides a good starting point.

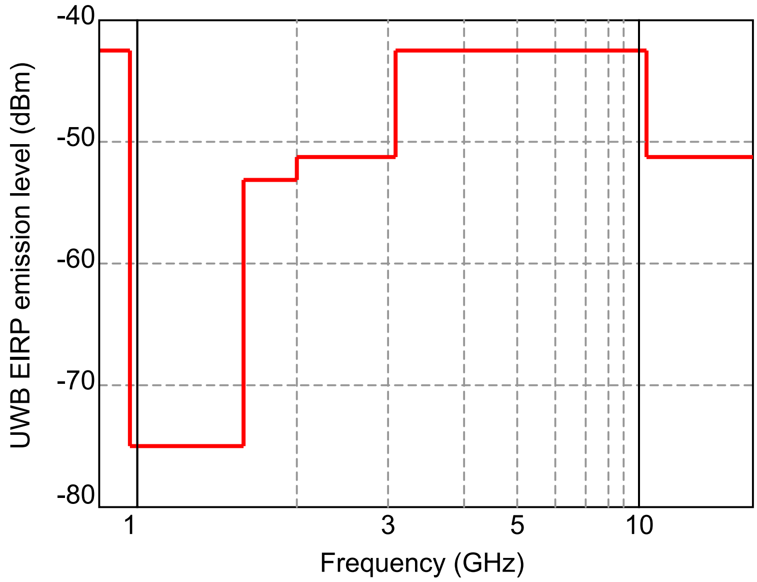

Figure 10. UWB EIRP emission level for indoor systems (FCC limits for America) [14]

An IEEE technical group has been established to produce a standard for UWB systems. 802.15.3a has two groups attempting to steer its decision on how UWB systems will operate. The MultiBand OFDM Alliance (MBOA), backed by Intel and Texas Instruments, propose the use of a transmission mechanism similar to that used by IEEE 802.11a and g. MBOA believe by dividing the available spectrum up into several bands and using OFDM, signals will be more robust and interference-resistant [15]. XtremeSpectrum and Motorola are backing a proposal for a more traditional use of UWB by not limiting signals to a smaller frequency allocation and using notch filters to limit emissions in restricted frequency regions. The MBOA proposal is currently more popular but not by a sufficient margin that promotes it to the standardisation phase.

[10] In line with 'Part 15' of the FCC rules, which allows the operation of many classes of low-power device without any requirement for licensing. There has never been an equivalent of this 'Part 15' in UK regulations

UWB is capable of supporting data rates up to 110 Mb/s [16] at a range of 10 m and provides range-rate scalability with possible use as a very high data rate carrier for short interconnections between devices. Emissions have low power and extend over a wide frequency region, hence UWB signals have a very low power spectral density. Such use of small signal levels over a wide frequency region requires the use of broadband, non-resonant antennas. Other hurdles (including global standardisation) and the objections of other spectrum users such as broadband and mobile 'phone companies stand in the way of UWB becoming generally available.

5.6 WLAN examples and future development

While the technologies under development as alternatives to IEEE 802.11 illustrate its downfall as a wireless platform for audio/video networking, market forces tend to favour the well established. As mentioned before, manufacturers have been forced to develop proprietary QoS support for their own products, such as Toshiba's FACE wireless TV. While this may be detrimental to a universal standard, proprietary solutions have reduced time to market and have enabled some manufacturers to release networked CE products which demonstrate home networking potential to consumers.

Media Centres look to be what most believe will provide homes with television, radio, music, video and Internet access but such devices are over and above what can be supported by current wireless networking technology. A networked DVD player manufactured by Go Video for the US market introduces the concept of networking and retails around US$300. As a standard DVD player, it plays DVD videos, video CDs, photo CDs and MP3 files from CD-Rs, as most modern players do. The device also includes a PCMCIA slot and is bundled with a wired Ethernet card with the option of a wireless IEEE 802.11b card. Network access does not allow streaming of DVD movies or video CDs but allows users to stream MPEG videos and MP3 files or slideshow JPEG photos on their television set from their PC. While many consumers may see such a device as a gimmick, it shows another facility available to them through connectivity. Single, incompatible devices, though, do not illustrate the power of home networking.

The same issue of incompatibility remains, and while it does, the universal network may never exist. Solutions for rich multimedia wireless networking such as HiperLAN2 and Magis have only been proven in the laboratory. A Toronto-based semiconductor and software start up has developed a possible solution and rather than market their technology as products, their business model revolves around licensing their technology to manufacturers. ViXS Systems Inc. have developed a chipset and software control, which provides high quality video over any IP-based network, including internal support for IEEE 802.11. ViXS technology revolves around two chips; XCode, a video distribution processor and Matrix, a wireless video optimised IEEE 802.11a baseband processor. Together with the so-called Intelligent Distributed Video (IDV) and Adaptive Bandwidth Footprint Matching (ABFM) software, the ViXS technology provides dynamic control over MPEG (and other format) video resolution and format in order to uphold a QoS guarantee of, for example, 30 frames per second (fps). The exciting feature of this system is that is adapts to match the video bandwidth to the capacity available in the network. ViXS have already demonstrated their chipset streaming video to a PDA (personal digital assistant). The software control automatically 'choked' back the video data stream so that it did not exceed the 15 fps, 320 x 240 pixel display limit, resulting in a data rate around 500 kb/s [17]. ViXS are collaborating with Intersil to ultimately develop products providing high quality video over the latest IEEE 802.11g standard.

ViXS suggest block specifications for a Media Centre and so-called thin client devices. Thin clients are stripped down receiving nodes, providing only the necessary functions in order to reduce their cost. Based on these, Figure 11 illustrates a possible (simplified) design for a digital television gateway and node.

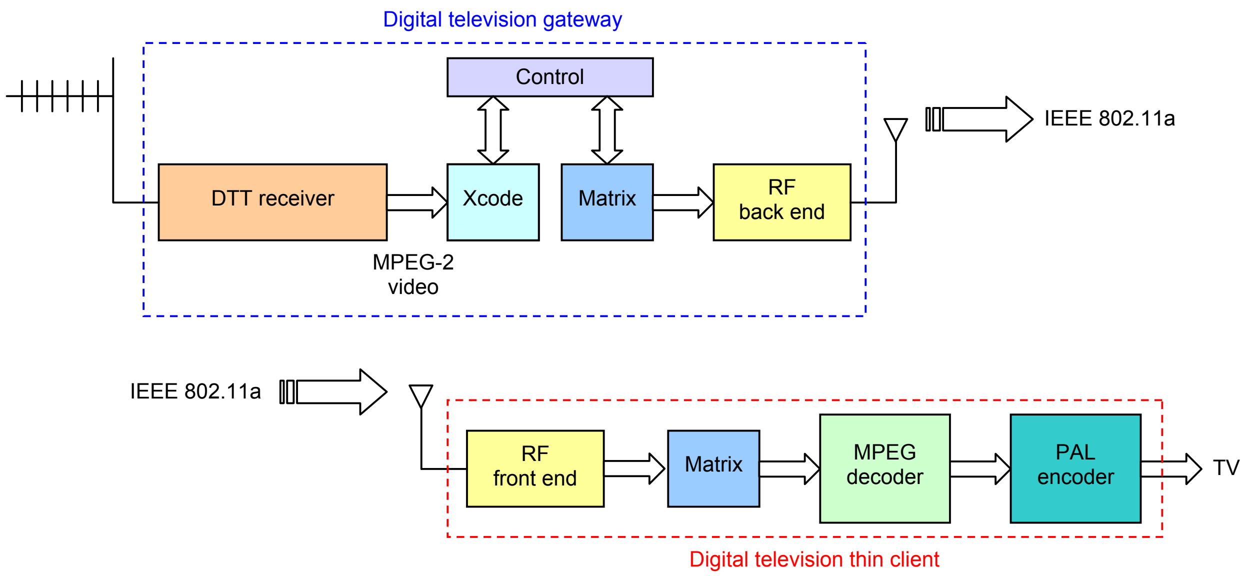

Figure 11. Simplified designs for digital television gateway and node networked devices

The Digital Home Working Group, a group of major companies including Microsoft, Sony, Nokia and Philips, announced in June that they would be working together to produce a set of guidelines for Wi-Fi compatibility and a universal plug-and-play standard [18]. The plug-and-play standard will ensure products will work together, and installation will be easy, no matter which manufacturers' devices are used. Such collaboration is very important before consumers can exercise freedom of choice with competition driving costs down.

6 The future

6.1 The fat pipe

In a model of television reception and home connectivity with outside services, the so-called 'fat pipe' is often referred to. Current digital subscriber line (DSL) technology is the closest we come to such a generic connection to multimedia services. A fat pipe is simply a high-speed data link, which carries all available broadcast media into the home as well as supplying the home with broadband Internet access. Homes with a DSL supplying digital television and Internet access enjoy much the same benefits but are restricted by the limited bandwidth of the connection and the whole service is currently limited to a small number of households[11]. While many homes currently employ separate cable distribution for television and data signals, future in-home distribution of these signals is likely to employ a single wireless network. A model for future in-home distribution is illustrated in Figure 12.

The fat pipe is connected to a Media Gateway device, which collects all incoming broadcast media and provides distribution throughout the home. The Media Gateway is normally depicted as a hybrid set-top box, providing many features such as television storage and DVD playback. Devices requiring a connection to one or more services supplied by the fat pipe each incorporate a thin client interface. A thin client provides minimum functionality, as each device, such as a television, only needs a subset of the services available and this keeps the cost to a minimum. Such a generic infrastructure also supports connectivity between devices and thus brings the benefits associated with a home entertainment network.

[11] Kingston Communications offer DSL services to residents in Hull only. The service includes broadband Internet access and Video-on-demand alongside digital television

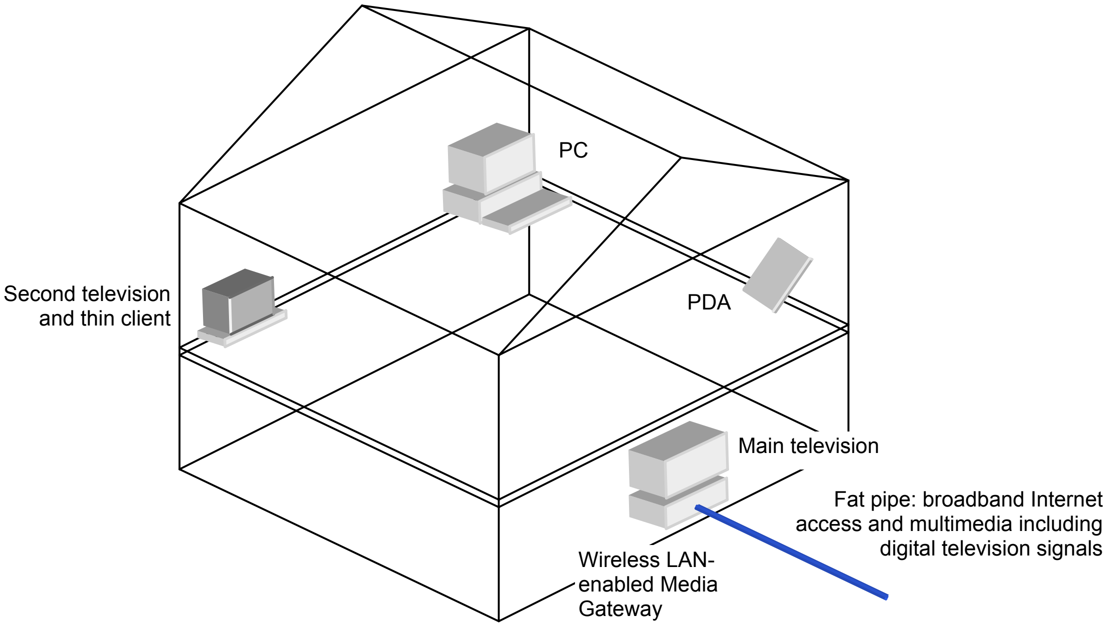

Figure 12. Future in-home multimedia distribution

6.2 PC and television convergence

As has already been mentioned in this document, television technology has begun to converge with computer technology in the latest generation of set-top boxes. Internet access is available through your television for example. Coming from the other direction, digital television and hard disk recording is available on your PC and Microsoft have developed a version of their Windows operating system to exploit such functionality. Windows XP Media Centre Edition is an operating system designed for multimedia PCs providing television capability. Together with additional hardware, Windows XP Media Centre Edition provides users with a single interface to access live and recorded television services, watch DVD movies, view photos and listen to MP3 music. With the addition of a remote control, users interact in much the same way as they would with a television or digital set-top box. As Microsoft is not a broadcaster or service provider, programme listings are sourced from the Internet and television pictures are sourced from whatever platform the

Figure 13. Windows XP Media Centre Edition

television hardware supports. While it is unlikely users will adopt a PC as their main television source, Windows XP Media Centre Edition PCs do provide a working example of how future Media Gateways might operate. The fat pipe is not yet a reality so the PC combines a variety of sources to provide the user with a single interface. As services grow in number, user interaction may well dictate whether consumers buy into such systems providing many different services. Windows XP Media Centre Edition provides all the same functions as the standard version of Windows XP and takes the standard length of time to start up. A cut-down version, providing only the media centre functions, running on a PC in a VCR-sized shiny metal case may well come close to being the Media Gateway, or set-top box of the future.

7 Conclusions

When regarding reception by portable television sets, the analogue terrestrial network is hard to replace. Analogue coverage is so complete, it is generally believed that a set-top aerial is adequate and, more broadly, many consumers believe television is synonymous with aerials. While analogue television permits consumers to put up with partial reception (i.e. reduced quality picture and sound), digital is either received or not. However, post switch-over, digital reception through sa et-top aerial will not provide a service for many of those who currently rely on set-top aerials for analogue reception. To conserve portability, technology must be introduced which does not require consumers to tether their portable sets to a rooftop aerial, satellite dish or subterranean cable link.

Wireless technology exists which can push video signals around the home. The difficulty comes in conserving flexibility and quality while keeping the cost to a minimum and providing a scalable solution for homes with a larger number of portable televisions. The technology detailed in this document provides consumers with two alternative solutions. The digital video sender (DVS) project would appear to tackle the problem from a television-orientated perspective and we will be testing a working version of their device soon. Millions of analogue video senders have been sold around the world and therefore it would be plausible to believe consumers find them easy to use. Use of DVS devices assumes a rooftop aerial providing adequate DTT reception for profile 1 or a satellite or cable connection for one of the higher profiles which accepts an external digital video source. Such solutions are likely to be over-complicated for those who currently source analogue television reception solely using a set-top aerial.

Wireless home entertainment networks are regarded as the future of in-home entertainment and connectivity between consumer electronics devices, making it easier to share media and pipe audio and video throughout the home. Through the growth of WLANs for commercial use, wireless technology is becoming affordable for home users but currently does not provide support for high quality multimedia. Developments by Magis Networks and ViXS are promising but as yet have not resulted in any actual devices. It is also likely that wireless networking technology will result in hybrid devices which may also provide solutions for point-to-point digital television distribution. The technology detailed in this document provides solutions for in-home distribution of digital television and hence assumes a source of digital television is input to the house via one of the available platforms.

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