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Scenario and use cases

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Abstract

This document describes the main scenarios for the BETSY project divided over the home environment and a hot spot. Afterwards the technical requirements are derived in chapter 5, limiting the scope of the project, but still including the important aspects for our research. We have written down detailed requirements for the network, the mobile devices involved and the coding characteristics of the content in our scenarios. Main conclusions are that the BETSY focus will be on 802.11a/b/g networks, point-to-point and multicast communication, including handovers. A maximum number of three video streams at the same time within one AP are considered. Special attention will be paid to the timing requirements in the case of user input that leads to changes in the number of streams or reconfiguration of existing streams. For the video coding format certain specific types of MPEG-4 scalable coding, sometimes compared with the currently popular MPEG-2 format, will be taken into account. For the mobile devices we will only take into account devices, which have the possibility of doing power management, as energy reduction is one of the project goals.

Several possible hardware/software platforms to do the verification of the theoretical results were investigated, but the actual decision which platform to use will only be made at the start of WP4, in order to take the latest developments into account.

The requirements derived, will be used as input to WP2 and WP3, defining their playground, while we will iterate and finally implement (a part of) the scenarios defined in this document in WP4. The scenarios will also be used to validate the found proposed solutions later.

Keyword list

Scenarios, user requirements, wireless networks, hot spots, home networks, video coding, MPEG, communication media, infrastructure

Table of Contents

1 Introduction

This document describes the reference scenarios and use cases for the BETSY project.

In chapters 2 and 3 we first investigate the state of the art technology in our problem domain, i.e. wireless networking with embedded devices in the connected home domain and on hot spots.

In chapters 4 and 5, we describe two scenarios, composed of several parts, covering different distribution aspects over the wireless network. The first one focuses on a home network, while the second one focuses on the situation within a hot spot. In order for a scenario to be successful it needs to address the user needs. The "user" for the BETSY project can be divided in two groups:

- The consumer at home or on the move
  We need to prove and demonstrate how the user's experience, in terms of the highest acceptable quality for the longest possible time, can be improved by the exploitation of a dynamically adapted infrastructure
  => *BETSY provides a solution*
- The application / system designer
  We need to prove and demonstrate how the engineer's design flow can be improved by the incorporation of QoS / time / resource trade-off capabilities. For example by reducing integration time of new features.

  => *BETSY is not a one-time solution*

Our scenarios should demonstrate and test:

1. *QoS* vs. Available *Energy* adaptation capabilities
2. *QoS* vs. Available *Bandwidth* adaptation capabilities
3. *QoS* vs. *Energy* vs. *Bandwidth* adaptations.

This scenario serves as basis for the extraction of more detailed technology requirements and use cases coming from the CE and mobile world. Abstracting and analyzing the use cases is necessary to find general applicable solutions, which are the goal of this project, instead of a one-time solution. For example quality changes as function of environmental changes or user wishes may turn out to be the right abstraction level instead of switching on a video on a PDA.

The scenarios are of course targeted at the first user group, i.e. the consumer at home or on the move. The explicit mentioning of the second 'user', i.e. the system designer, is to remember that the analysis and investigations should lead to a more general solution and not a one-time solution.

With these detailed scenario and the technology requirements in this document as input, WP2 and WP3 will define a high level, more abstract, architecture and decide on the platform architectural choices. Task 4.1 of WP4 will need the use cases for the BETSY test-bed, which will also evaluate parts of the scenario.

2 Infrastructure

This section discusses the technologies that play a role when streaming video over both the home network and the so called hot spots. First the infrastructure of the home network is discussed; both wired and wireless devices are expected. Next, the most likely candidate media are described in more detail. We especially discuss the availability of mechanisms that make the communication technology suitable for video streaming. Then, the similarities and differences with respect to the hot spot infrastructure are presented. After these media, the properties of the streams using the media are discussed. The section concludes with measurements done on the bit rates supported by the communication media and on the bit rates required by the video streams.

2.1 Infrastructure

2.1.1 Home network

The home network can be built up from different network segments. In a wired network, a device has to be connected to a cable infrastructure before this device can communicate with other devices in the network. Typical wired network technologies are: Switched Ethernet, IEEE 1394, and HomePlug (using power lines).

Wireless communication media (IEEE 802.11, IEEE 802.15.x) have the advantage that no extra cables are needed. Within the wireless context, two types of devices can be considered: (1) portable devices (5 kilos or less), and (2) mobile devices. The second type of device (e.g. a PDA or Laptop) must be connected wirelessly, since this type of device is permanently on the move. In particular mobile devices may be introduced into the home as guest devices with limited rights. For the portable type, the wireless network is a convenience. These devices are rarely transported, 2-3 times a day at most. For example, a portable device (e.g., a 17 inch plasma screen) can be picked up, transported to another room, connected to the mains and communication is established. Currently two wireless communication modes are known (1) ad hoc and (2) with Access Point. In the first case no specific infrastructure is needed, in the second case an Access Point (AP) is needed.

When wired and wireless connections exist together in the home, APs can connect the wireless devices to the wired infrastructure. One AP for an IEEE 802.11 based network may be sufficient depending on the network use and conditions. In the future, when home-network deployment increases, several (interconnected) APs will be desirable or even essential. The interconnection between APs can be done in two ways (1) cabling the APs, which brings us back to the cabling problem but in a limited sense (since the AP normally are fixed) or (2) connecting them wirelessly which may be complicated if obstructing walls exist. Currently, sharing a single Internet connection with other devices is the main driver for the setup of an in-home network. Consequently, all devices both wired and wireless have connectivity to the Internet.

At the time of writing the point of control of the in-home network is still not determined. Many home networks employ devices that combine an Internet modem with wireless and wired connectivity and both firewall and routing functionality. When only one device combines wired and wireless connectivity it can be a central controller of the entire in-home network. For telecommunication and cable companies this is an interesting operation model.

Another possibility is that a PC will take control of the entire home network. Yet a third possibility is that the number of devices will be so large, or have such a different nature, or the network has such a topology that a central controller will not be accepted. In this case the network has to be managed in a distributed way. Currently all options are still open and it is necessary to investigate a network management, which can deal with those different situations.

2.1.2 Hot Spot

A Hot spot is a place where wireless Web access is available to the public (for a fee or for free). For users of portable computers equipped for wireless, a hot spot is a wireless LAN node that provides Internet connection and virtual private network (VPN) functionality. In a similar way, a hot zone is a wireless access area created by multiple hot spots located in close proximity to each other.

The main communication mode in a hot spot is the access point (AP), as the WLAN is set up by attaching to the wired network a base station (BS) (also called an AP), which relays the traffic between the wireless users and the wired network. In public areas covered by a number of APs, the user load is in general dynamic and unevenly distributed among the APs. It is possible that some APs (so-called “hot spots”) are congested by many users and cannot admit more requests, while their neighboring ones are serving few users and the bandwidth is underutilized. In order to alleviate such congestion, an ad hoc relaying wireless LAN framework can be introduced. This way, a neighboring AP serves a mobile user in a hot spot. The failure rate is reduced as well as the bandwidth utilization is improved in such hot spot networks. [15] In the hot spot context, Wi-Fi (Wireless Fidelity) is a term for certain types of wireless local area network (WLAN) that use specifications in the 802.11 family and assures product interoperability. The particular specification, under which a Wi-Fi network operates, is called the “flavor” of the network.

Interoperability is also intended among Wi-Fi hot spots and the 2.5G/3G systems as the deployment of hot spot wireless LANs can enhance the performance of 3G cellular networks. Within the context of 3G cellular systems, WLANs are a complementary technology that can be used to provide users with high data-rate services in localised areas. This is achieved by means of handovers between 3G cellular access networks and WLAN APs. Interoperability between WLAN (802.11 family) and the 802.16 standard for Wireless metropolitan area network (WMAN) is being considered as well and 802.11/802.16 integration is discussed in the following section. Unless adequately protected, a Wi-Fi network can be susceptible to access by unauthorized users who use the access as a free Internet connection. Any entity that has a wireless LAN should use security safeguards such as the Wired Equivalent Privacy (WEP) encryption standard, the more recent Wi-Fi Protected Access (WPA), Internet Protocol Security (IPSec), or a virtual private network (VPN). Therefore, issues such as security access, user authentication or data encryption become very important.

An essential ingredient of hot spots is not only the handovers within the hot spot but also the handover management between the hot spots. The Internet of the future will be very different compared to the current wired Internet as the number of mobile users is constantly increasing. As a result, the Internet will consist of a collection of hot spots that are connected by a backbone routing network, which is the current known Internet. Hence, nomadic use of computers should be supported. However, considering the possible applications, the use of real-time multimedia applications while being mobile is expected to become increasingly important. As a result, not only nomadic use but also seamless mobility between the different APs should be considered (or provided). This requires a lot of management at the network layer, because indeed the packets should be routed towards a different AP seamlessly not to lose multimedia content. The current Mobile IP solution will need a tight integration with the lower layers to be able to deliver the required performance to the application. As discussed in [16] also the technology used at the link layer has a great impact on the Handover delay performance. Depending on the load of the new hot-spot, towards which we are being handed over to, the delay incurred to get access to the new channel might be significant (up to 2 seconds in [16]). This delay is a result of the DLC/MAC layer only, and is added to the Mobile IP delay. To obtain a seamless handover, it is required to have the ability, at DLC/MAC layer, to be connected temporarily to different APs. Considering the high mobility or non-overlapping hot spots this might not always be feasible. Hence, other techniques to improve the collaboration between the PHY, MAC, network and application layer will be needed to achieve the required performance even when the number of handovers is large.

2.2 Communication media

In this section we describe four important (upcoming) connectivity standards that have been considered as the basis of a home network, combining PC and CE devices. These four are: the well known switched Ethernet, the wireless Ethernet, the upcoming Ultra Wide Band and the HomePlug based on power-line. We describe the aspects of the technology that is of interest to high quality video streaming over such a technology. We also indicate which of the previously mentioned standards is adequate for the deployment of hot spot infrastructures and we introduce the standard 802.16 (WMAN).

2.2.1 Switched Ethernet, IEEE 802.3

Switched Ethernet is a point-to-point connection and not a bus as the original Ethernet. The switched Ethernet is based on the well-known Ethernet CSMA/CD technology. Actually, there are two transmission speeds freely available 10 Mbit/s and 100 Mbit/s with Gbit/s transmission capacity upcoming. The Switched Ethernet wire connects on one side to the node and on the other side to a switch. Several lines are connected to one switch. The switches are interconnected with high-speed lines. For example 25 devices can be connected to 5 Ethernet switches in groups of 5 with 10 Mbit/s lines. The five Ethernet switches are interconnected to a 6^{th} switch with 100 Mbit/s lines. In a home possibly one to two switches suffice. Frames are received, buffered and sent on according to the sending policy inside the switch. An option is to use cut-through switching. Cut-through switching allows switching the stream between lines when the destination address has been received. Cut-through switching is replaced by store-and-forward switching when the lines are occupied. Such a switching architecture facilitates streaming without perturbations between nodes. Collisions can occur inside the switches. The emptying of the buffers in the switch depends on the bandwidth of the ingoing lines and the sharing of the outgoing lines by the applications. When two incoming lines support streams of 10 Mbit/s and want them switched to one outgoing line of 10 Mbits sec, half of the packets are lost.

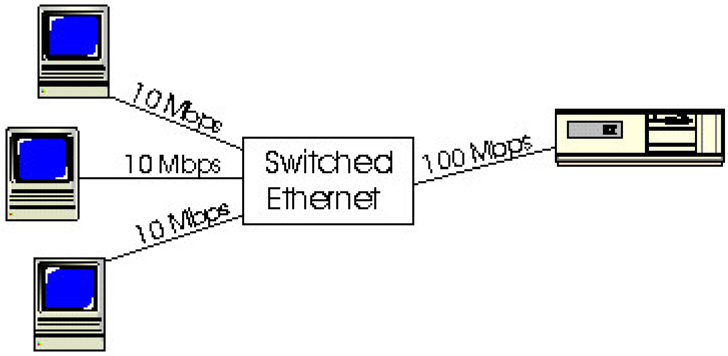

Figure 1 switched ethernet configuration

In Figure 1 a mixed network based on 100 Mbit/s Ethernet and 10 Mbit/s Ethernet is shown. All three PCs can simultaneously send data with a 10 Mbit/s rate to the switch, and from there to the storage device via the 100 Mbit/s line.

2.2.2 IEEE 802.11

In this section we will describe the IEEE 802.11 family of standards for wireless Ethernet. Table 1 presents an overview of the main physical standards, the frequency and the modulation technique and the corresponding theoretical maximum bandwidth as well as the number of channels.

Substd	Frequency	Max. Bitrate	#Independent Channels	Modulation
802.11a	5 GHz	54 Mbit/s	±12[1]	OFDM
802.11b	2.4 GHz	11 Mbit/s	3	DSSS
802.11g	2.4 GHz	54 Mbit/s	3	OFDM

Table 1 Physical Properties of IEEE 802.11 Standards

Both the 5 and 2.4 GHz frequency bands are unlicensed bands and are thus subject to interference. For example the microwave interferes in the 2.4 GHz band. Some cordless phones also operate at 2.4 and 5 GHz (see [15]). At the time of this writing most existing products reside in the 2.4 GHz frequency band. The 5 GHz band is not so popular in Europe. At the Medium Access Control (MAC) layer, switched Ethernet and IEEE 802.11 both use Carrier Sense multiple Access (CSMA). However for wireless Ethernet, Carrier Sense Multiple Access / Collision Avoidance (CSMA/CA) is used since collisions cannot be detected. The MAC function is named Distributed Coordinator Function (DCF).

The wireless medium is generally less reliable than a wired medium. At the MAC level, acknowledgements and retransmissions are introduced to improve performance in the sense

[1] Dependent on local regulations

that the average data rate will go up, compared to when acknowledgements and retransmissions are done in one of the higher ISO-OSI layers. This complicates meeting delay and jitter bounds. On the other hand it allows specifying the maximum number of times a packet can be retransmitted. In the presence of an AP, packets have to be transmitted either to or from an AP. This restriction leads to a duplication of all traffic between two non-APs leading to twice as much bandwidth being used and delay. The IEEE 802.11e standard proposes enhancements for MAC Quality of Service. At the time of writing, this standard is not yet finalized. We base our discussion on the draft 2.0[2] of January 2002. The proposed 802.11e standard adds methods for priorities and reservations for Quality of Service.

An interesting improvement is the removal of the restriction to transmit packets either to or from an AP. This facility halves the bandwidth use when two non-access point stations communicate. A priority mechanism adds queues per priority to the IEEE 802.11 standard. The realization of priority on the medium is through variation of the parameters AIFS, CWMin, and CWMax of the MAC layer. Through their adjustment, one can basically add lower priorities to the IEEE 802.11 standard. In this way, traffic can be less important than legacy traffic. This is problematic since legacy devices now immediately have the highest priority, whereas one normally wants to assign legacy devices a low priority. There is also a reservation-based protocol. By sending a Poll packet the hybrid coordinator grants a transmit opportunity for a certain time to the receiving station. The wireless station is supposed to stick to this time bound, but it may transmit as many packets as it can. Of course, the coordinator cannot force a station to follow this rule. IEEE 802.11e specifies the frame formats for a request (given by a so-called TSPEC) for a certain Traffic Stream and an “acknowledgement” of a request. The Traffic Specification (TSPEC) (of draft version 2) captures the following stream properties: inter arrival time, nominal packet size, minimal physical rate, minimum data rate, mean data rate and upper bounds on jitter and delay.

2.2.3 Ultra Wide Band (UWB), IEEE 802.15.3a

In this section we discuss high-speed wireless connections with an advertised bit-rate of at least 100 Mbps. For High-Speed Wireless there seem to be three possibilities: (1) to use a high frequency at which more spectrum is available for unlicensed use, (2) to use multiple antennas, and (3) to use ultra-wide band techniques. This section quickly describes the first two as a comparison with the UWB technique.

For the first, currently, free-to-use spectrum is available at 5 GHz, 17 GHz, 24 GHz, and 60 GHz. But at such high frequencies propagation of the signal is quite different from that at lower frequencies. There are still a number of problems with the propagation range, the allowed power and the implementation cost. We will not discuss these problems here. A second possibility to go to higher bit-rates is the use of a multiple antenna solution. The use of multiple antennas can benefit practically all modern wireless networking standards because with multiple antennas it is easier to reconstruct a signal that has followed multiple paths thereby interfering with itself. Normally this reconstruction poses requirements on the modulation of the signal, leading to lower bit-rates. The antennas have to be at least half a wavelength apart. The IEEE 802.11n group has been formed to develop a multi antenna extension to the IEEE 802.11 family. For 802.11n, currently expected bit-rates are not clear but expectations range from 100 to potentially 320 Mbit/s. The standard is targeted at the end of 2005.

[2] August 2004 draft is version 9.0.

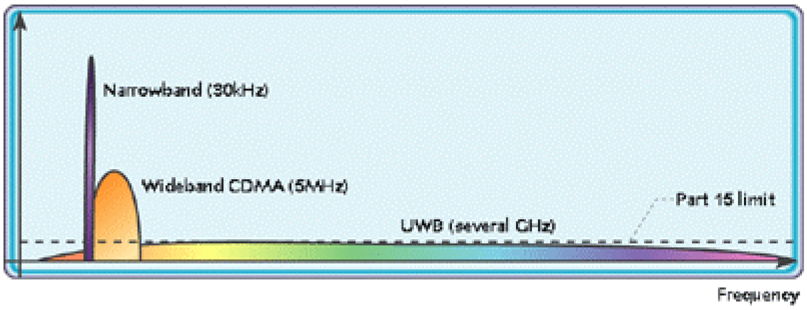

Figure 2 Ultrawideband in the radio spectrum

"Ultrawideband" promises bandwidth ranges from about 40Mbit/s up to 600Mbit/s, and in a longer term data rates go up to gigabits per second. At this moment it is still difficult to judge the actual possibilities of this technology. In traditional wireless technology a small frequency range is used to transmit the signal. This requires that such a frequency is reserved for — read: licensed to — the user. In current wireless standards such as 802.11 wideband techniques are applied to allow operation in license-free bands: A larger part of the spectrum is used but at such a power level that interference is limited to very short distances. The underlying assumption of UWB is to use a very large part of the spectrum, hence the name ultra wide band but at a very low power in order not to interfere with the signals transmitted by those that have licenses for parts of the band (see Figure 2). Data is conveyed by transmitting pulses of roughly nanosecond-duration with an appropriate time/amplitude modulation. This process is sometimes compared to the transmission of Morse signals. Given the low power that is used, it is not easy to reconstruct the original signal from what was received, since that may be "hidden" by the noise. The reconstruction process is involved and power consuming.

This signal reconstruction also determines the theoretical maximum bandwidth. Furthermore this bandwidth is very much dependent on the distance. The highest bit-rates can only be achieved at a very short range or at a much higher power, which could introduce risks for humans. The behavior in practice is still under research, and the influence that multiple UWB transmissions have on each other is also still unclear. The US Federal Communications Commission has allocated UWB the spectrum between 3.1 and 10.6 GHz, currently used by satellite transmissions. Many countries do not permit commercial UWB because they only allow technologies that operate in a small frequency range [3]. Given the large interest from the community, there is already a serious interest in standardizing communication technologies at such high rates. IEEE 802.15.3a is working in this direction. This group will build a higher-bitrate physical channel under the IEEE 802.15.3 standard MAC, which was basically derived from Bluetooth with a a CSMA/CA MAC addition.

2.2.4 Homeplug 1.0

The communication medium for HomePlug is the installed electricity grid in the home. Therefore, Homeplug is seen as a good contender for the communication medium of the home, because all the wiring is already installed. The technology is readily accepted in the US where many products are sold based on communication via the electricity wires e.g. X10. In

Europe the licensing issue is still controversial. The HomePlug 1.0 standard has adopted Orthogonal Frequency Division Multiplexing (OFDM) with a Cyclic Prefix (CP) like IEEE 802.11. The bandwidth can vary from 1 Mbit/s to 14 Mbit/s continuously depending on channel conditions. The HomePlug 1.0 MAC is a modified CSMA/CA protocol with priority signaling [1]. The Homeplug devices address each other directly and do not communicate with an AP as for IEEE 802.11. The standard provides four priorities. A device asserts its priority by setting a bit in a priority window. Devices with lower priority packets back-off. Devices with the highest priority for a given transmission period, choose a random back-off window within this priority. After every collision, devices wait over a longer back-off window. In contrast to IEEE 802.11, HomePlug chooses its random back-off interval larger than the one chosen during the former collision.

2.2.5 Technology for Hot Spot Infrastructures

From the above-mentioned standards, the 802.11 family of Wireless LANs is also the basis of the hot spot infrastructure. The basics of a hot spot is a wireless LAN. Larger hot spots use multiple base stations (or APs) to provide coverage of the indoor (or outdoor) micro-service area of the hot spot. The APs are networked together through conventional LAN hubs and switches and aggregated into a high-speed backhaul link to the Internet. The key difference between a hot spot and a conventional corporate WLAN is the traffic itself. In the case of the hot spot, virtually none of the traffic stays within the hot spot. It is all headed out to the Internet. In contrast, WLAN traffic is largely contained within the LAN. This means that the backhaul links for a hot spot need to be much larger than those normally required for corporate or enterprise Internet access.

Most wireless LAN installations today comply with 802.11b, which is also the basis for Wi-Fi certification from the Wireless Ethernet Compatibility Alliance (WECA). In some cases, you should deploy 802.11b networks to take advantage of the installed base of 802.11b-equipped users, for example to maximize the number of subscribers for public WLANs. There's been much debate over the use of 802.11g vs. 802.11a for satisfying needs for higher performance WLAN applications. It has been claimed that because of its superior performance capacity, 802.11a will likely dominate the high performance WLAN market in the near-term and distant future. Moreover, the 802.11h standard addresses the requirements of the European regulatory bodies and reduces interference issues of the 802.11a by applying Dynamic Frequency Selection (DFS) and Transmission Power Control (TPC). This way, 802.11h is enabling sales of 802.11a networks in Europe, which will eventually result in higher sales volumes at lower prices. On one hand, as 802.11g is an extension to the 802.11b, the basis of the majority of wireless LANs in existence today, there is compatibility between 802.11b and 802.11g and it is relatively easy to upgrade 802.11b APs to be 802.11g compliant. (only ofr 2.4 GHz). On the other hand, the three (3) available channels in 802.11g limit the number of non-overlapping APs to three (as with 802.11b), which makes the channel assignment difficult when needing to cover a large area where there is a high density of users. Another important issue is the considerable RF interference from other devices working in the same frequency range (2.4Ghz) as 802.11g.

The 802.11a works in the 5GHz frequency band with twelve separate non-overlapping channels. As a result, up to twelve APs can be set to different channels in the same area without them interfering with each other. This makes AP channel assignment much easier and significantly increases the throughput the WLAN can deliver within a given area. In addition, RF interference is considerably reduced because of the less-crowded 5 GHz band. Due to higher frequency, however, the range of the 802.11a is somewhat less than 802.11b or 802.11g. This requires a greater number of APs but also increases capacity by channel reuse. Due to the higher frequency used, the range is lower for 802.11a. But even with this limitation, 802.11a can sometimes deliver better performance than 802.11b at similar ranges from the AP. Another important issue is limited interoperability , since a 802.11a terminal cannot communicate with a 802.11b AP. This is solved by multimode radio cards that support multiple 802.11 PHYs (.a,.b,.g) in a single card or by using AP with a dual 802.11a/b solution, which interoperates with both. Finally, 802.11a products cost approximately 30 percent higher than 802.11b. Nevertheless, 802.11a could be a better long-term solution, especially when future performance needs are not well known.

Standards like Ultra-Wide Band (UWB) or Homeplug 1.0 seem more suitable for home networks than for hot spot networks. Ultra-Wide Band is not considered a good candidate for a hot spot network due to its reduced power level (due to interferences with other RF communications in the same frequency range), which limits it to very short distances. However, the feature of reduced power renders UWB more adequate for home networks as it is suitable for a short range of up to 10 meters (while 802.11 defined range is up to 100 meters) where data rates of up to 600 MB/s are expected. As the transmission distance increases, data rates decrease drastically to few kbps. Moreover, it highly differs from all other Radio Frequency communications, which makes interoperability with other standards a hard achievement.

In the next section, a standard is discussed, which can complement and interact with WLAN hot spots.

2.2.6 IEEE 802.16 (Wireless Metropolitan Area Network)

The 802.16, also called WiMAX, standard defines the Wireless MAN (metropolitan area network) air interface specification. This wireless broadband access standard could supply the missing link for the “last mile” connection in wireless metropolitan area networks. Many customers are outside DSL’s reach and/or are not served by broadband-capable cable infrastructure. The wireless broadband standard could be serving these customers.

802.16a is an enhancement to 802.16 for non-line-of-sight extensions in the 2-11 GHz spectrum. It delivers up to 70 Mbps at distances up to 31 miles. 802.16e is the enhancement to 802.16 that enables connections for mobile devices. Wireless broadband access is set up like cellular systems, using base stations that service a radius of several miles/kilometers. These base stations can connect to a 802.11 hot spot or a wired Ethernet LAN. Seamless roaming is provided between heterogeneous 802 networks, targeted at standardization of hand-overs, so that devices are interoperable as they move from one network type to another.

Today, 802.11 users maintain connectivity as long as they move around a hotspot. With 802.16e users will be able to stay connected by 802.11 when they are within a hot spot, and then connected to 802.16 when they leave the hot spot but are within a 802.16 service area.

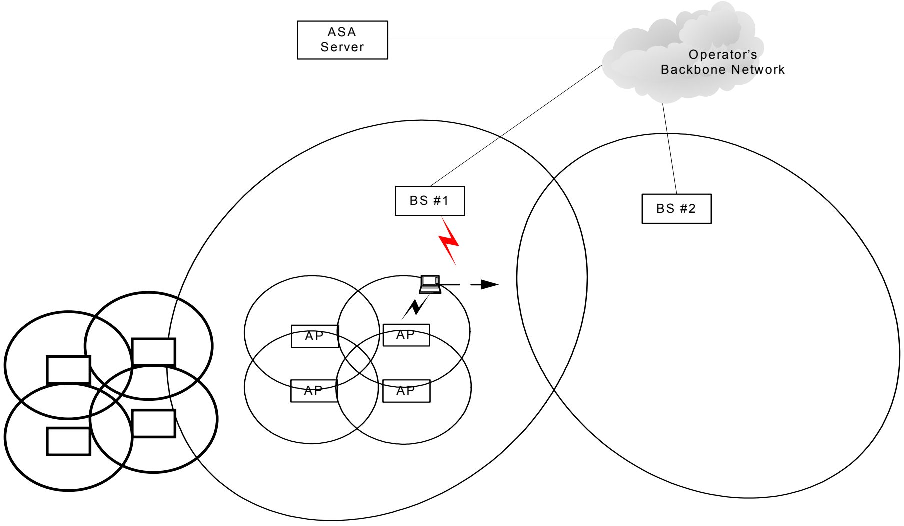

Figure 3. Integration of 802.16/802.11

The 802.16 WMAN is an infrastructure technology, appropriate when large coverage is intended and addressing a low population density, while the 801.11 WLAN is a hot spot technology with a moderate coverage and aimed at serving dense aggregations of people and users.

The scenarios where handovers take place among hot spots (802.11) and 802.16 vary:

1. A user of a 802.11 service goes out of the hot spot coverage. The degradation of WLAN signal is detected and handover occurs seamlessly from .11 to .16 WMAN without user intervention.
2. A user of a 802.16 service goes into blind areas of WMAN coverage, where 802.11 WLAN is deployed. In this case, the degradation of WMAN signal is detected and handover is performed seamlessly active from .16 to 11 without user intervention.
3. A user of a 802.11 service drives through or out of the hot spot coverage. Because of the high-speed movement and short overlapping distance, a new 802.16 connection is established with very short latency.

Several issues regarding handover and internetworking models in the integration of 802.16 and 802.11 are still open.

2.2.7 IEEE 802.20

Unlike the 802.16e specification, which is based on an existing standard (802.16a), 802.20 is starting from scratch. This means that products based on 16e will likely hit the market well before 802.20 solutions. The 802.20 seeks to boost real-time data transmission rates in wireless metropolitan area networks to speeds of 1Mbps or more based on cell ranges of up to 15 kilometers or more, and it plans to deliver those rates to mobile users even when they are traveling at speeds up to 250 kilometers per hour. This would make 802.20 an option for deployment in high-speed trains. There is some overlap between the .16e and .20 standards, but 802.20 addresses in particular high-speed mobility issues. It is argued that 802.20 is a direct competitor to third-generation (3G) wireless cellular technologies, therefore interoperability between 3G and 802.20 (4G) is not likely to happen.

2.2.8 UMTS (3rd Generation Mobile Systems)

As the penetration of GSM is approaching 100 percent and reaching network saturation in certain areas, operators and manufactures are preparing the start of the third generation (3G) of mobile communications. 3G Systems are intended to provide a global mobility with wide range of services including telephony, paging, messaging, Internet and broadband data.

The third generation of mobile systems uses different technologies than the GSM system. The main differences are the use of Wideband Code Division Multiple Access (WCDMA) and the use of Asynchronous Transfer Mode (ATM) in the radio access network. Table 2 shows the theoretical coverage and data rates of UMTS systems.

Coverage	Transmission Rate	Maximum velocity of Receiver
UMTS Mega Cell (world-wide vehicular)	144 Kb/s	Unlimited
UMTS Macro Cell (rural-suburban)	144 – 384 Kb/s	500 km/h
UMTS Micro Cell (urban)	192 – 384 Kb/s	120 km/h
UMTS Pico Cell (building and vicinity)	384 Kb/s – 2 Mb/s	10 km/h

Table 2 UMTS coverage versus theoretical transmission rate

In Europe interoperability between UMTS (3G) and WLAN hot spots is likely to predominate, as 802.11 technologies are complementary to 3G. The WLAN-GPRS solution helps both operator revenues and wireless data markets. Cellular convergence is key to turn 802.11 PWLANs into revenue generating opportunities. Convergence with cellular systems can help by providing the user with uniform access, common billing and ease of roaming. Therefore, it is highly possible that WLANs become an important complementary technology to 3G cellular systems and will typically be used to provide hotspot coverage. In [17] the capacity enhancement and benefits of cellular/hotspot interworking has been quantified. Ultimately, beyond 3G networks will expand to offer data rates in excess of 100 Mb/s and interwork with a number of technologies including satellite communications, WLANs, and digital broadcast technologies. Eventually, such networks will provide integrated and seamless services via a common IP-based network.

WLANs are now seen as a complementary technology that can be used to provide users with high-data-rate services in localized high-traffic-density locations (e.g. city centers and business districts). In the integration of heterogeneous networks, such as WLAN and UMTS, vertical handovers are required. Vertical handovers occur when users switch between both networks. The natural trend is to utilize high-bandwidth WLANs such as 802.11 in hotspots and switch to wireless wide area networks (WWANs) such as UMTS when the coverage of WLAN is not available or the network condition in WLAN is not good enough. Such a procedure is called vertical handover. Horizontal handovers refer to switches between base stations (BS) or APs in a homogeneous wireless system. Experiments in [18] show that seamless roaming between WLAN and UMTS can be achieved and better performance can be obtained than with the traditional scheme. Horizontal handovers within IPv6 wireless networks, such as WLANs are managed with the Mobile IPv6 protocol. Several extensions to Mobile IPv6 have been proposed to reduce the handover latency and the number of lost packets: hierarchical Mobile Ipv6 and Fast Handover protocol (which allows the use of layer 2 triggers to anticipate the handovers). [19] Handover latency can sometimes be too long for real-time multimedia applications, strongly degrading the multimedia stream. In order to avoid too frequent and fast horizontal handovers between APs in a WLAN (higher mobility user), a vertical handover can be made to switch the user to the UMTS base station, which covers a bigger range reducing the amount of handovers needed.

2.3 Networking Video streams

Audio/Video streams are important to the overall user experience in the home environment. For a company like Philips that wants to stand out and compete on video quality, it is very important to be able to have the highest quality possible. In this document we focus on A/V streams. A very important parameter, though difficult to measure, is quality as perceived by the user. Video coding experts use a value, Peak Signal to Noise Ratio (PSNR), to indicate the video quality of a rendered picture compared to the original reference picture. PSNR compares individual pictures, without taking the time aspect into account. Consequently PSNR is not always a good indicator for quality of streamed video. A few rules of thumb exist to forecast perceived picture quality, but as they are rules of thumb they are not always true or undebatable. Obviously hiccups and delays are not perceived as good. Also, great fluctuations in quality are perceived as lower quality than an on the average lower but constant quality [14].

In technical terms, video streams pose strict conditions on the delay and jitter. Delay is the total amount of time between sending and receiving/showing a specified piece of the video. A delay of less than 100 ms is preferred. When watched at 10, the recorded 8 o’clock news can suffer a delay of a few seconds up to minutes; on the other hand, the finals of the world championships should be minimally delayed (below 100 ms) to prevent hearing the neighbors before seeing the actual players score. With a video chat, delay should also be minimal (figures are mentioned as low as 10 ms which is based on a maximum round-trip time) since it directly determines the possible response times of the user and thereby the value of the application. So, in general, delay should be kept small and, if there are return channels, the delay has to be an order of magnitude smaller than delay without a return channel. Jitter, the variation in delay, can only be accommodated by using buffers in end devices or intermediate devices. For cost reasons, jitter should be minimal.

Video streams usually have a high bit-rate. There is a relationship between video quality and the corresponding bit-rate: the video quality can be reduced such that the amount of data in the video diminishes. The associated reduced data rate reduces the required bandwidth. Preparation of the same video with different qualities allows the selection of a video with a given data rate.The relation of bit-rate/bandwidth requirements to quality can be modeled via the use of a few quality classes with an associated bit-rate and bandwidth requirement respectively. A straightforward implementation of this uses a number of pre-encoded streams and switches between the complete streams depending on available bandwidth. A different type of implementation does not switch between complete streams but only adds extra information, e.g. by employing so-called scalable video.

Scalable video streams make it possible to encode the video in multiple layers dependent on the quality that is required. The scalable stream makes it possible to adapt the amount of streamed data to the available bandwidth. A low amount of data corresponds to a lower quality. The advantage is that recognizable pictures are transported even with high fluctuations in available bandwidth. Without scalable streams the pictures tend to be completely lost. The video content is separated in n+1 layers. The Base Layer (BL) contains a low quality video. The n Enhancement Layers (ELi, with i=1, …, n) provide additional quality. Two layers BL+EL1 provide higher quality than the BL alone. A total of k+1 layers BL+EL1 +...+ ELk provides better quality than k layers. A correct use of the layering involves at least the BL and k consecutive ELi with $1 \le i \le k$ and $0 \le k \le n$. Current values for n are 1 and 2. The sending of the BL needs a much lower bandwidth than the sending of BL and the n EL. When a video is sent over a poor connection, it is important to assure that at least the BL arrives and only additionally layers EL1 to ELn arrive in that order. The BL layer is transported in BL packets and the ELi layer is sent in ELi packets. For a given frame first the corresponding BL packet is sent, the BL packet arrives even when the available bandwidth is low. Consecutively, dependent on the available bandwidth, EL1 packets are sent, followed by EL2 packets and higher layer packets until ELn is sent. Once scalable video is deployed, the quality of the video source can be expressed in the number of employed layers. The total amount of required bandwidth can be adapted to the operational needs for example low quality displays, or small window sizes do not need all n+1 layers.

2.4 Bandwidth measurements

In Table 3 some numbers are shown to give an idea of the bandwidth values that are involved. Bandwidth of communication media is mentioned versus the range or cable length. For all wired media, copper cabling is assumed.

Medium	Range	Total bandwidth	Measured bandwidth	PER / Loss probability[3]
Switched Ethernet	100 m	100 Mbit/s	90 Mbit/s 40 Mbit/s	0.02 0.0003
IEEE 1394	72 m	400 Mbit/s		< 10^-17
Homeplug 1.0	2 m 10 m 20 m	14 Mbit/s	4-6 Mbit/s 3-6 Mbit/s 3-6 Mbit/s	0.1
IEEE 802.11a	2 m 10 m 20 m	54 Mbit/s	18-24 Mbit/s 10-15 Mbit/s 6-7 Mbit/s	0.5

[3] Probability of packet loss is difficult to estimate given the many masquerading techniques at link layers.

IEEE 802.11b	2 m 10 m 20 m 50 m	11 Mbit/s	5-6 Mbit/s 5-6 Mbit/s 5 Mbit/s n/a	0.5
IEEE 802.11g	2 m 10 m 50 m	54 Mbit/s	7-14 Mbit/s 6-8 Mbit/s n/a	0.5
Bluetooth	2 m	800 Kbit/s	570 Kbit/s	0.25
Ultra Wide Band	10 m	100 Mbit/s	n/a	n/a

Table 3 measurement of communication medium bandwidth

Measurements are taken from [1][2][4][5][6][7][8][9]. The switched Ethernet losses occur in the switch when there are more than two streams passing through the switch. Bandwidth of wireless medium depends on range and objects along the path. The bandwidth required by the MPEG-2 video code is shown in **Error! Reference source not found. Error! Reference source not found.**. Three layers are provided: (1) a BL with PSNR quality 30, (2) a BL+EL1 with PSNR quality 35, and (3) a BL+EL1+EL2 with PSNR quality 40. For non-scalable video, data is provided with PSNR 30, corresponding to the “base layer” column and PSNR 40. The measurements on the size of the generated scalable MPEG-2 video are rather pessimistic. A video has been taken with small objects with fast movement and many scene changes. The required bandwidth calculation is based on MPEG2 EL composed of I frames only.

Results for MPEG-4 temporal and spatial scalability are shown in Table 5. The way temporal and spatial scalability are performed is described in [10]. For MPEG-4, numbers are given for the medium motion Foreman sequence, as well as for the more demanding high motion Calendar and Mobile sequence. Additionally, the numbers are averaged over these both sequences and given in the tables as well, so as to represent an average sequence considered in the scenarios. High-encoded quality is considered for QP (Quantisation Parameter) 3 (corresponding to PSNR around 40 dB), while medium quality and low quality for QP 7 and 12 respectively (corresponding to PSNR ranges of 32-25dB and 29-33dB). The first Intra frame is always encoded with QP 3, while the P or B frames are encoded with QP 3, 7 or 12. Large differences exist per video. Also large fluctuations occur at a frame level. The GOP structure in one I frame, and several P frames, also affects the bit-rate. Generally speaking the larger the GOP the lower the bit-rate but a higher sensitivity to frame losses. In the table also the bandwidth needs of a file transfer over 100 Mbit/s Ethernet is shown to compare bandwidth consumption by file transfer with video consumption.

	resolution	code	BL / unlayered	EL1	EL2	sum	unlayered
PSNR			30	35	40	40	40
QCIF	176x144	MPEG-2	0.6 Mbit/s	0.7 Mbit/s	1 Mbit/s	2.3 Mbit/s	1.5 Mbit/s
CIF	352x288	MPEG-2	1.5 Mbit/s	1.7 Mbit/s	2.5 Mbit/s	5.7 Mbit/s	3.8 Mbit/s

SDTV	720x576	MPEG-2	3 Mbit/s	4 Mbit/s	6 Mbit/s	13 Mbit/s	8.7 Mbit/s
File transfer						90 Mbit/s	

Table 4 measurements of MPEG-2 video bandwidth requirements

Temporal Scalability

	Resolution	code	Sequence	BL	EL	Total
QCIF	176x144	MPEG-4	Foreman QP3	338 kbps	247 kbps	585 kbps
QCIF	176x144	MPEG-4	Foreman QP7	131 kbps	75 kbps	206 kbps
QCIF	176x144	MPEG-4	ForemanQP12	83 kbps	38 kbps	121 kbps
QCIF	176x144	MPEG-4	Mobile QP3	1.14 Mbps	0.91 Mbps	2.05 Mbps
QCIF	176x144	MPEG-4	Mobile QP7	475 kbps	324 kbps	799 kbps
QCIF	176x144	MPEG-4	Mobile QP12	250 kbps	139 kbps	389 kbps
CIF	352x288	MPEG-4	Foreman QP3	1.12 Mbps	0.87 Mbps	1.99 Mbps
CIF	352x288	MPEG-4	Foreman QP7	402 kbps	231 kbps	633 kbps
CIF	352x288	MPEG-4	ForemanQP12	262 kbps	118 kbps	380 kbps
CIF	352x288	MPEG-4	Mobile QP3	3.85 Mbps	3.26 Mbps	7.1 Mbps
CIF	352x288	MPEG-4	Mobile QP7	1.62 Mbps	1.24 Mbps	2.86 Mbps
CIF	352x288	MPEG-4	Mobile QP12	900 kbps	580 kbps	1.48 Mbps

	Resolution	code	Quality	BL	EL	Total
QCIF	176x144	MPEG-4	High	750 kbps	578 kbps	1.32 Mbps
QCIF	176x144	MPEG-4	Medium	300 kbps	339 kbps	639 kbps
QCIF	176x144	MPEG-4	Low	167 kbps	88 kbps	255 kbps
CIF	352x288	MPEG-4	High	2.48 Mbps	2.06 Mbps	4.54 Mbps
CIF	352x288	MPEG-4	Medium	1 Mbps	0.73 Mbps	1.7 Mbps
CIF	352x288	MPEG-4	Low	580 kbps	340 kbps	920 kbps

Spatial Scalability

	Resolution	code	Sequence	BL (QCIF)	EL (CIF)	Total
QCIF/CIF	176x144	MPEG-4	Foreman QP3	532 kbps	1.92 Mbps	2.45 Mbps
QCIF/CIF	176x144	MPEG-4	Foreman QP7	183 kbps	550 kbps	733 kbps
QCIF/CIF	176x144	MPEG-4	ForemanQP12	108 kbps	261 kbps	369 kbps
QCIF/CIF	176x144	MPEG-4	Mobile QP3	1.95 Mbps	7.17 Mbps	9.12 Mbps
QCIF/CIF	176x144	MPEG-4	Mobile QP7	775 kbps	2.8 Mbps	3.61 Mbps

QCIF/CIF	176x144	MPEG-4	Mobile QP12	378 kbps	1.37 Mbps	1.74 Mbps

	Resolution	code	Quality	BL	EL	Total
QCIF/CIF	176x144	MPEG-4	High	1.24 Mbps	4.5 Mbps	5.74 Mbps
QCIF/CIF	176x144	MPEG-4	Medium	479 kbps	1.67 Mbps	2.14 Mbps
QCIF/CIF	176x144	MPEG-4	Low	243 kbps	815 kbps	1.05 Mbps

Table 5 measurements of video bandwidth requirements (Temporal and spatial scalabilities)

Video measurements are taken from [11] [12] [13]. Assuming the stream goes directly from the AP to the destination or from the source to the AP, it can be seen that IEEE 802.11b (with its net 5 – 6 Mbit/s upto 10 meters) may support up to four CIF two layer videos of medium quality or one two layer CIF video of high quality. . IEEE 802.11a (net 15 Mbit/s at 10 meters) will support one full SDTV video with one two-layer high quality CIF video, or two two-layer SDTV videos. Recall that when source and destination are both wirelessly connected to the same AP, the stream uses the medium twice and only half of the contents can be supported. File transfer measurements show that the consumed bit rate is limited by the bandwidth of the medium.

In this respect it is interesting to realize that especially in the home environment attenuation by walls and other objects can be significantly reducing the effective bandwidth between two points. Table 6 shows typical attenuation numbers in the 1.5-5 GHz band [25],[26].

Concrete wall	8-12 dB
Double plasterboard	3-4.5 dB
Soft partitions	2- 4 dB
3 m racks with books –paper products (bookshelves)	3 –5 dB

Table 6*, Typical attenuation factors (1.3 – 5 GHz) for indoor propagation through various types of walls*

2.5 Infrastructure for video

In section 2.4, it is shown that switched Ethernet easily supports a number of video streams, depending on the path of the streams through the switch(es) losses may occur. Measures are needed to counter the effect of these losses on the video quality. Although the bandwidth requirements of the video streams are bounded, unbounded needs can come from i.e. file transfers. Measures must be taken to prevent bandwidth starvation. A 10 Mbit/s Ethernet cable supports 2 to 3 reasonable / medium quality SDTV video streams or 1 streams of high quality. The Homeplug, IEEE 802.11a and IEEE 802.11g performances are disappointing over distances of 10 meters and more. They come close to the low IEEE 802.11b performance. A wireless link support at most one medium quality video over a short distance with current technology. The promises of UWB still need to be proven. It is our belief that larger high quality screens will be connected to a video source with a wire. Small mobile screens and medium quality portable screens (17 inch) are more likely to be well served by a wireless connection.

In particular, for the hot spot scenario the characteristics are similar than to those of the WLAN 802.11 standards with some differences such as a less even number (?) of users per AP or the presence or more outdoor scenarios where the distances are increased. This may result in bad channel conditions and thus, reduce the available data rate or in the case where a higher number of APs is available, this implies that frequent handovers need to take place among APs (in particular for users with a certain degree of mobility). One of the main issues is to perform seamless handovers that have no impact on the communication and as a result, on the video quality.

3 Home network scenario and analysis

In this section we describe three user scenarios of home network applications involving video streaming. Next we provide a quantitative analysis of the possible combinations of streams. The scenarios are subsequently analyzed for their technical issues and possible solutions are discussed.

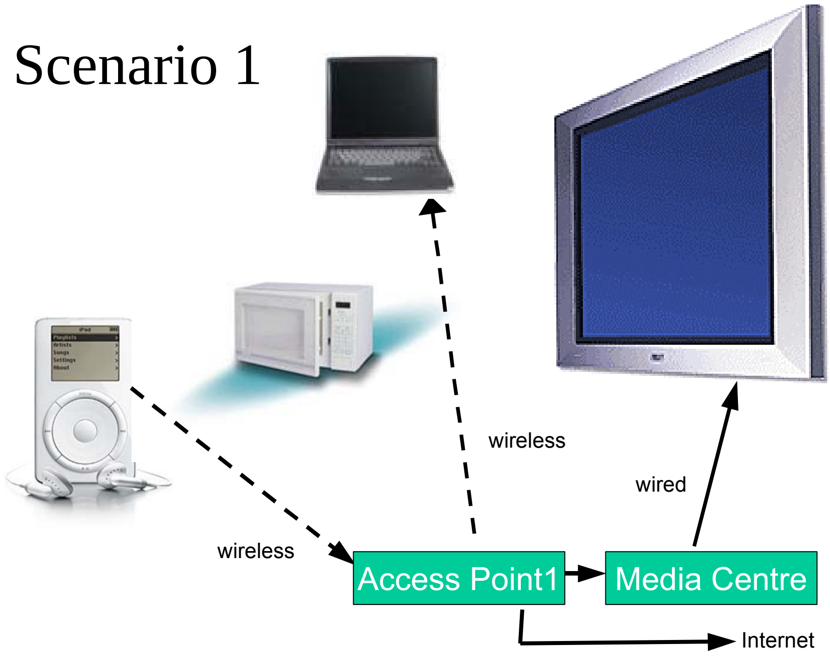

Figure 3 Scenario 1

3.1 Scenario 1

The devices involved in this scenario are:

- a large screen TV,
- a media center,
- an access point / internet gateway (AP1),
- a wireless Portable Storage Container (PSC),
- a laptop, and
- a microwave oven

We assume that the PSC and laptop connect wirelessly to the AP. The microwave can distort the wireless signal over a limited distance within the kitchen[4]. The AP is also the gateway to

[4] There are many different opinions and results on the actual influence of microwave ovens on the wireless signal. The impact can depend on the type, the shielding, the power usage, the location of and the distance to the

the Internet. The media center connects via a switched Ethernet cable to the TV. The AP and media center can be connected via an Ethernet cable or integrated into a single box. One 802.11g based and one 802.11b based wireless channels are possible simultaneously. See Figure 3.

The scenario:

1. *Visitors to the family enter the family's home with their PSC. They will show video recordings that they stored on their PSC.*
2. *Before father joins the gathering, he starts a search program on his laptop to browse the Internet for interesting videos and downloads them into the laptop.*
3. *In the mean time the PSC is connected to the wireless home network and the video contents of the PSC are from storage displayed onto the large screen of the family.*
4. *After some time mother goes to the kitchen and switches on the microwave.*

The PSC is placed at a distance of less than 5 meters from AP1 and uses the 802.11g standard for communication.

3.2 Scenario 2

The second scenario is a continuation of the first one.

The additional devices involved in this scenario are:

- a wireless tablet (smal mobile screen), and
- a second AP (AP2).

We now assume a second access point, AP2, is present near the bedrooms and the swimming pool and connects to the wired backbone of the home. The tablet connects wirelessly to the closest of the APs. The tablets use 802.11b for its long-range properties. See Figure 4.

microwave oven. Here we use the microwave oven merely to introduce temporary, short-lived, fast fluctuations on the wireless LAN.

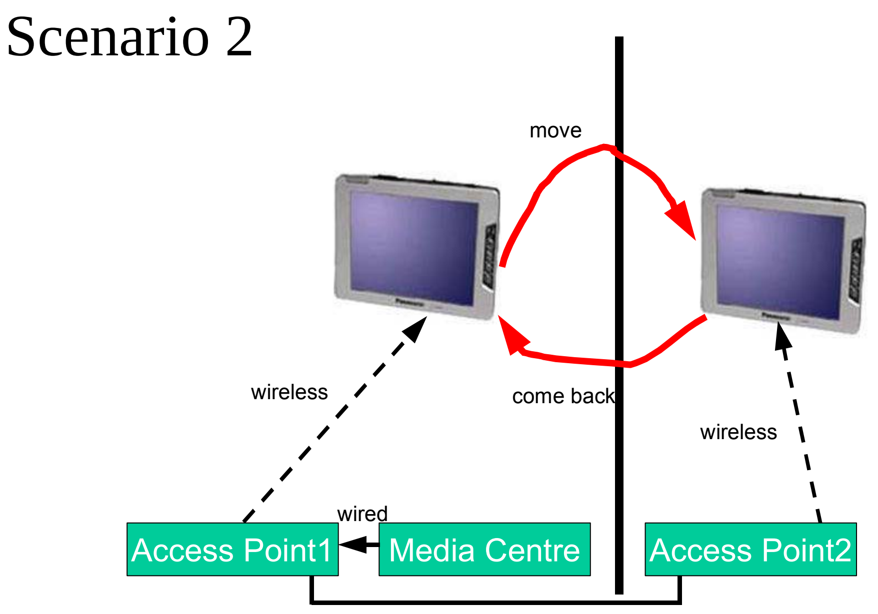

Figure 4 Scenario 2

1. *Betsy, the daughter of the house thinks it all too boring, and she selects "Finding Nemo" from the media center to display it on her tablet.*
2. *She notices that in the living room the quality is very low. (AP1)*
3. *She goes to her own room and lies back to enjoy the movie. (switch to AP2)*
4. *She is asked to look after her little brother swimming in the in-door pool by her mother, so she goes to the pool with her web-tablet. Now she is far from AP2 and only has access to 1mbps.*
5. *When mother informs her of the snacks that have been prepared in the microwave, she takes her brother and her tablet back to the living room continuing watching the video she started.*

3.3 Scenario 3

The third scenario refines the two previous scenarios.

The additional devices involved in this scenario are:

- a wireless tablet (smaller mobile screen) with a camera facility

This tablet connects wirelessly to the AP in the living room. Again 802.11b is used as connecting standard. The microwave consumes all wireless bandwidth in the kitchen. See Figure 5.

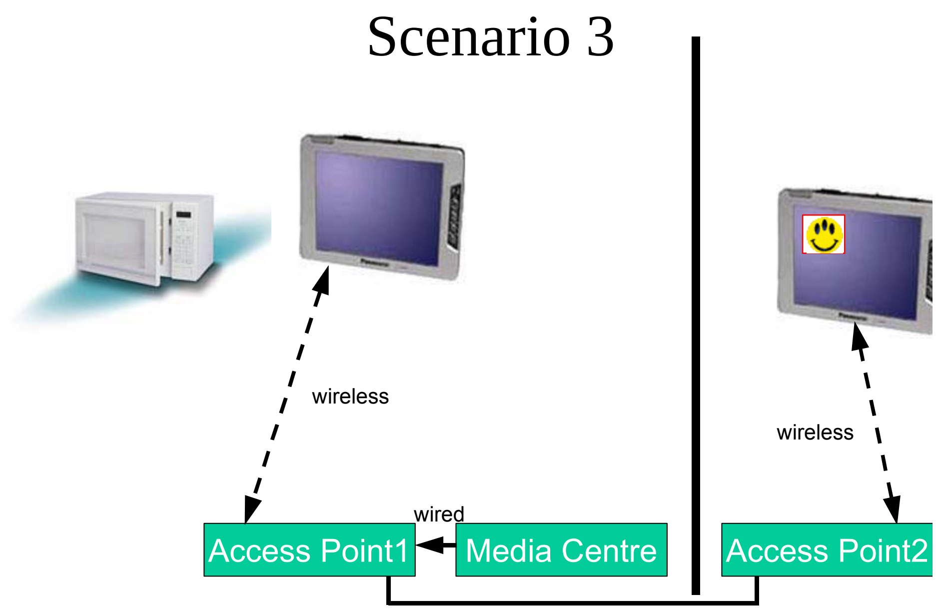

Figure 5 Scenario 3

1. *When mother went to the kitchen, she took the tablet with its video-chat camera with her.*
2. *Mother wants to start a video chat with Betsy to inform her about the snacks being prepared.*
3. *But while the snacks are prepared, mother is too close to the microwave: the wireless network is therefore too flaky and the connection cannot be made.*
4. *Mother waits until the microwave is finished and then again, but now successfully, contacts her daughter. The daughter accepts that a picture in picture (PiP) appears on her tablet, the quality of the main video degrades, her mother appears in the PiP, and the sound is switched to the PiP. "Will you come down" mother asks, "We're having your favorite snacks".*

3.4 Quantitative analysis

The *first scenario* assumes that all Ethernet connected series of equipment do not influence each other. Demands on the wired network are relatively low. Demands over the wireless are high. Assume an IEEE 802.11g connection of less than 2 meters with a constant capacity of 14 Mbit/s. The microwave is far removed from the AP1, PSC and PC. Demands on the wireless are:

- One SD 3-layer video of 7 Mbit/s from PSC over 802.11g wireless to AP1 over Ethernet cable to screen
- Maximum file transport from Internet over Ethernet to AP1 over 802.11b wireless to PC (all 6 Mbit/s that are not consumed)

In the *second scenario* there are three states: tablet in living room, tablet in bedroom, tablet at in-door pool. The demands on the network with the tablet in living room can be fulfilled as follows.

- One SD 3-layer video of 14 Mbit/s from PSC over 802.11g wireless to AP1 over Ethernet cable to screen
- One SD 1-layer video of 3 Mbit/s from media center over Ethernet to AP1 over 802.11b wireless to tablet
- Maximum file transport from Internet over Ethernet to AP over 802.11b wireless to PC (3 Mbit/s left over)

The demands on the network with the tablet in bedroom can be fulfilled as follows.

- One SD 3-layer video of 14 Mbit/s from PSC over 802.11g wireless to AP1 over Ethernet cable to screen
- One SD 3-layer video of 6 Mbit/s from media center over Ethernet to AP2 over 802.11b wireless to tablet, when BETSY moves towards the pool, she will only receive one layer of the video or the video has layer size has to be scaled down as only 1 Mbit/s is available
- Maximum file transport from Internet over Ethernet to AP1 over 802.11b wireless to PC (6 Mbit/s that are not consumed)

In the *third scenario* there are two states more than the three mentioned under scenario 2 (microwave on, microwave off). The requirements on the network in the state with the microwave off can be realized:

- One SD 3-layer video of 14 Mbit/s from PSC over 802.11g wireless to AP1 over Ethernet cable to screen
- One SD 2-layer video of 6 Mbit/s from media center over Ethernet to AP2 over 802.11b wireless to tablet
- One CIF 2-layer video of 3.2 Mbit/s from camera over 802.11b wireless to AP1 over Ethernet to AP2 over 80211b wireless to tablet.
- Maximum file transport from Internet over Ethernet to AP1 over 802.11b wireless to PC (2.8 Mbit/s left over)

With the microwave on, requirements are as follows:

- One SD 3-layer video of 14 Mbit/s from PSC over 802.11g wireless to AP1 over Ethernet cable to screen
- One SD 3-layer video of 6 Mbit/s from media center over Ethernet to AP2 over 802.11b wireless to tablet, near the pool BETSY only receives the base layer.
- Less than one CIF 1-layer video of 1.7 Mbit/s from camera over 802.11b wireless to AP1 over Ethernet to AP2 over 802.11b wireless to tablet.
- One microwave removes 4 Mbit/s from 802.11b within kitchen area.
- Maximum file transport from Internet over Ethernet to AP1 over 802.11b wireless to PC (4.3 Mbit/s left over)

3.5 Problem analysis

Any stream in a (wireless) network will be subject to external factors that could negatively impact the resulting video quality. It is necessary to appropriately address these issues while at the same time meeting deadlines to assure rendering without delays. Typical causes leading to varying circumstances are (1) interference, (2) a device fluctuating between being in- and out-of-range, (3) new streams entering the network, and (4) handovers. A management and control model that deals with these kinds of problems will have to be based on the specific characteristics of those perturbations.

Frequent changes, such as interference are often of such a short duration that it is not possible to *react* in a timely manner and a preventive measure has to be taken. Typically this results in open-loop control systems, where associated actions are often taken at a low level (e.g. in or close to the hardware), generally based on a coarse differentiation mechanisms introduced at a higher level. Less frequent changes, such as the introduction of a new stream can, and should, be dealt with in a different way. The acceptable response time is sufficient to use slow high-layer (e.g. software-based) solutions and base the control strategy on received feedback or other inputs. This approach is usually called network management. We will now turn to the four example causes, indicated above, and show how a management and control model could deal with them.

Interference and other unpredictable packet losses manifest themselves through a decrease in the available resources, often bandwidth. A typical example is the microwave in Scenario 1 and 3. The home network of the neighbor is another example. The high frequency of the variation demands a low-level prevention-based approach. A solution is to build an adaptive application, following this general scheme: the application or video codec, uses its knowledge of the video domain to divide the video into a number of parts that are very important, important and less important. Next this separation is made sufficiently explicit such that at a low level in the network stack a decision to drop the least important data can easily be taken. A simple example is to differentiate the layers of a (scalable) MPEG video, and add different packet priorities to packets containing a specific layer and to drop low priority packets corresponding to higher layers when bandwidth is insufficient.

Another approach is to use FEC (Forward error correction) by protecting the layers and even the different frame types in the layers at a varying degree, such that the important I frames are heavily guarded by Reed-Solomon codes with better correction capabilities than P or even B frames. This technique is referred to as Unequal Level or Erasure Protection (ULP/UXP) [19]. FEC is routinely used in wireless digital broadcast technology, like DVB-S and DVB-T.

A device fluctuating between in/out of range can normally be dealt with at the logical link (2^{nd}) layer. However, too quick changes may lead to an overload of events at a higher (software) level. E.g., when a device continuously (dis-)announces its capabilities and services. A different example is the tablet trying to initiate a video-chat in Scenario 3. Generally, thresholds are used to smoothen out reactions of a controller dealing with fluctuations. In a distributed system a membership algorithm can be used to determine whether a device is part of the group or not. When not, its data are rejected by the recipients.

The introduction of a new stream – or a stream leaving the network – can also be seen as a change in the availability of the resource. When streams continuously adapt to the available resources, the quality decreases whenever new streams are introduced and eventually the quality of all streams will be poor. While the user of the last stream is immediately confronted with a poor quality, users whose streams are already running are confronted with consecutive decreases in quality. For those users the unexpected and not-clearly attributable decrease in quality leads to an unsatisfactory experience. Sometimes, when resources drop below a certain level, an application cannot work at all.

Admission control is the technique that ensures that existing streams do not suffer from a reduction of resources they need for normal operation. A new stream that potentially threatens existing streams is not admitted, or only at lower quality. In step 2 of Scenario 2 the daughter's stream is only admitted at a lower quality. For a pleasant user experience, admission control is essential. However, it works by locking streams and hence users out. In specific cases this is not desirable and the resource allocations have to be broken. In Scenario 3 step 4 the PiP overrules the video of the daughter; this is likely what the user wants. The user should feel in control during this process. In the scenario this realized by having the daughter authorize the appearance of the PiP. The requirements on user-friendly admission control when dealing with multiple streams at different quality levels are complex. Since at the same time response time is in the order of tenths of a second, advanced (software) solutions to the basic control problem become feasible.

Handover essentially combines the two previous issues. After a certain moment a device can be seen to be associated with a new AP. Consequently, the path of the stream through the network has to be changed. In Scenario 2 step 3 the stream is handed over to an AP, which was not in use. Consequently (if it is detected) the quality can be increased. In Scenario 2 step 4 the opposite handover happens. Other streams already use this path. The policy of admission control suggests that the handed-over stream is considered as new and it should again pass admission control. If admission fails the stream cannot be handed-over. This is not always required by the user for whom the stream is not considered new. An alternative is to fall back to the adaptability of the applications based on the layered video. All applications now faced with an overloaded network segment on their path will adapt by dropping layers automatically. User control is limited and all videos will equally degrade. Another alternative is to reserve capacity at all relevant APs at the start of a stream that can roam. This potentially leads to a large over-reservation restricting the number of streams that can be used concurrently. The final choice must be based on user studies.

We conclude that adaptive applications are suitable to deal with "fast" changes. For "slow" changes with multiple streams, network QoS management and control becomes possible and generally leads to a better user-experience than a straightforward dependence on the adaptability of the application. A hand-over is an intrinsically difficult situation, since the user does not consider the stream "new", and a quality reduction is also not desired.

3.6 Scenario driven conclusions

The scenario, not surprisingly supports our conclusions of Section 2.5. Wireless links will support at most two medium quality video streams from/to portable devices. This function is illustrated with the tablet of the daughter, the PSC of the visitors, and the camera for the kitchen-bedroom conferencing.

Mechanisms are needed to handle fast fluctuating bandwidth changes in the wireless medium due to interference, and moving in and out of range. Other mechanisms are needed to allocate the network resources in a fair and comprehensible way to the individual video streams. Through membership protocols a consistent view is built with which video streams are involved and which are not. It is shown that some of these allocation choices depend on the situation and the roles of the involved users. Video streams are relatively well behaved as they have a maximum bandwidth requirement. A file transfer can consume the complete bandwidth. For a good bandwidth allocation to streams, the bandwidth requirements of the individual applications need to be harnessed.

4 Hot spot scenario and analysis

In this section three user scenarios of hot spot applications are given that involve video streaming. Subsequently, these scenarios are analyzed with respect to stream combination and technical issues.

4.1 Scenario 1

The devices involved in this scenario are:

- Different APs
- a camera equipped helmet
- a media center
- a TV

We assume 2 houses (Betsy's and Alice's), each with an AP and additional APs on the street covering Betsy and Alice's neighborhood[5].

When Betsy drives the bike she wears a protective helmet that is equipped with a battery-powered helmet.

The scenario:

1. *Because Betsy's mother wants to keep an eye on her, the media center will ensure that the video feed is connected via a switched Ethernet cable to a small portable screen in the kitchen where Betsy's mother is preparing dinner.*
2. *Betsy decides to go to Alice's. Between her own house and her destination, Betsy's camera is connected seamlessly to different APs without a loss of video information along the way.*
3. *The road to Alice's is downhill and Betsy starts running.*

Assumptions:

- The media center acts as a server to which the helmet camera connects, in order to stream its video to.
- The fixed Ethernet connections between the APs are no bandwidth bottleneck.

4.2 Scenario 2

This scenario is a continuation of the previous scenario.

The scenario:

1. *Betsy arrives at Alice's and her camera connects seamlessly to different APs without a loss of video information along the way*
2. *Betsy mother goes back to the living room and watches Betsy on living room TV.*
3. *Focused on the games she plays with Alice, Betsy forgets to load her camera batteries.*

[5] Not so unrealistic : a more than sufficient WLAN coverage is already exisiting nowadays in e.g., Silicon Valley.

4. *Betsy's mother is informed of the lower power state of the camera and has to choose between 15 minutes of high quality video or more than a half hour lower quality video. Her mother chooses the latter option, as she knows Betsy can take some time to stop playing and walk home.*
5. *Betsy's mother starts to watch an entertainment show and she looks at Betsy's camera view in a PiP. When she sees that Betsy leaves Alice's home, she put Betsy back in the main screen again, swapping the entertainment show into the PiP.*
6. *While Betsy returns home, her mother can observe her surroundings watching lower quality video.*

4.3 Scenario 2

This scenario is a continuation of the first two, with additional camera equipped helmets and media centers/TVs.

The scenario:

1. *The next day, Betsy makes an excursion with her friends around the neighborhood. All children are equipped with camera helmets, so that their parents do not need to worry.*
2. *Betsy being popular, she has many friends. The generated video traffic is too much for a single AP so that some of Betsy's friends are connected to the next best AP. The children connected to the AP of Betsy's house have to share the bandwidth of the AP. Since the distance from the other AP is higher (the coverage area can partly overlap with the first AP as the use of different frequencies per AP avoid interferences) Betsy's friends will have to share a lower total bit rate and consequently encode video at a lower bit rate.*

4.4 Quantitative analysis

The hot spot outdoors analysis is discussed here. The indoor situation corresponds to the one presented in the previous section except that the use of different displays is also considered in this case. Transcoding might be needed to transfer Betsy's video signal to the handheld.

In the *first scenario,* one can assume that the hot spot infrastructure consists of 802.11a APs as they offer the largest range of considered 802.11x standards (see Table 3). Considering that APs will be positioned along the road in such a way that one is never separated by more than 20m from an AP (e.g, by placing APs alongside the road every 40m), a single user will at least get around 6 Mbit/s, which is sufficient to send layered MPEG-4 CIF, even for high demanding sequences at high quality

In the *second scenario* the total energy is limited. Energy consumption can be reduced by limiting the encoding capabilities of the MPEG-4 encoder on board the camera helmet e.g, as follows: CIF BL+EL ➔ CIF BL ➔ QCIF being the required bit rates gradually reduced and with values respectively around 1.7 Mbps, 1 Mbps and 640 kbps. In turn, this will lead to less information that needs to be transmitted, allowing for energy savings in the modem. The limiting factor in this second scenario is not the bandwidth, but rather the energy consumption and the seamless handover capacities. In the *third scenario* the limiting factor is the total available bandwidth. This can be remedied in two ways: (i) limiting the encoded video quality as in the second scenario, and (ii) connect some cameras to the next best AP. Considering 6 children connected to the best AP and 4 connected to the next best AP, the available bandwidth for the first set of children is around 15 Mbps (2.5Mbps for each child) while for the second it is around 5 Mbps (1.25 Mbps for each child) These available bit rates allow for children in the first AP to transmit two-layered MPEG-4 CIF at medium quality or the CIF BL encoded at high quality, for children in the second AP either the BL of CIF (halved temporal resolution) at medium quality, two-layered CIF (full temporal resolution then) at low quality or two-layered QCIF at high quality.

4.5 Problem analysis

Basically the same conclusions hold as described in Section 3.5, with the following extensions:

4.5.1 High-mobility

It has to be taken into account that the mobility of the device accessing the AP can be higher than in the indoors scenario, which leads to an additional factor negatively impacting the resulting video quality.

4.5.2 Energy constrained device

In addition to the reasons described in Section 3.5, a new motivation exists for “graceful degradable” video e.g., through a layered approach: energy constraints at the mobile encoding end. By scaling back the quality of the video, an energy consumption reduction is achieved both in the video encoder as well as potentially in the modem.

4.6 Scenario driven conclusions

Overall, the same conclusions hold that in Section 3.6, but additionally, one has to take care of:

- Seamless handover at higher mobility
- Bandwidth limitations arising from a higher number of users per AP
- Energy consumption limitations at the mobile device

5 Technical requirements

In this section, the scenarios are analyzed and their technical requirements are extracted and analyzed. The analysis shows the technical background and typical realization approaches.

Both scenarios involve video/audio input sources, streaming of A/V data over a network, and reception of such streams on different devices. Two major factors involved are restrictions on available bandwidth for the streaming over a wireless network and the restricted amount of energy (battery capacity) for the mobile clients. The requirements will be analyzed according to the major topics input data, streaming, wireless networks, power management for embedded processors, mobile display devices, etc.

5.1 Input sources and devices

The two scenarios represent two radically different input sources:

- The home scenario uses existing media sources, either as existing files in the usual file formats like MPEG-1,2,4 and AVI or WMV, or as digital media streams which are broadcasted by TV stations in MPEG-2 transport streams (TS) via cable, satellite or terrestrial antennas. In these cases, the actual encoding is not part of the scenario, and thus the source format and compression type is not influenced by energy or bandwidth constraints, meaning that different grades of compression and image resolution can be provided depending only on the requirements of the network and the display devices.
- The hot spot scenario uses a small portable camera as real-time source, which must be compressed on–the-fly and under the battery power constraints of the mobile sender (i.e. the helmet camera)

Digital broadcast sources (DVB) usually are in the form of MPEG-2 Transport Streams, which consist of up to seven multiplexed Elementary Streams with varying average bandwidth of ca. 4.5 Mbps, with SDTV resolution (720x576) video and possibly multiple audio streams. Because of the limited bandwidth of terrestrial (DVB-T) channels, there are usually only 4 streams with about 3-4 Mbps provided. While DVB-T is already suitable for mobile receivers, the next standard DVB-H will even more support handheld devices by providing not a continuous, but a bursty transmission (IP datacast caroussel), which can be used to exploit energy-saving options in the receiver (idle mode). DVD normally also uses MPEG-2, but the streams are usually additionally encrypted for copy protection (CSS – Content Scrambling System). Media files in the Internet use a plethora of compression methods and file formats, either the standardized MPEG container or vendor-defined formats like Microsoft AVI, Apple Quicktime MOV or Real Media in combination with compression methods like MPEG-1,2,4 or WMV. In addition, most of these files provide usually smaller display resolution like CIF (352x288), like for promotional trailers and music videos.

Electronic cameras, as they are used in the hot spot scenario, are currently often based on CMOS technology, enabling the use of reduced resolutions and higher speeds as the traditional CCD technology. Often, a compromise must be taken between the acquisition speed (i.e. frame rate) and the camera resolution, at least because of the limited data bandwidth between camera chip and processor, and, indirectly, the energy consumption of the video transmission. For the intended application (surveillance and monitoring), CIF or QCIF are common formats.

MPEG-1 and MPEG-2 provide interoperable ways of representing audiovisual content, commonly used on digital media and on the air. The MPEG-4 standard extends this to many more application areas through features like its extended bit rate range, its scalability, its error resilience, its seamless integration of different types of 'objects' in the same scene, its interfaces to digital rights management systems and its powerful ways to build interactivity into content. This makes MPEG-4 the standard for multimedia transmission for the fixed and mobile web. Other existing standards such as the Advanced Video Codec (AVC, MPEG-4 Part 10) or the Scalable Video Codec (SVC) highly increase the complexity with respect to MPEG-4. Therefore the MPEG-4 Part 2 based with scalability extensions will be investigated in our scenarios, as it provides the required scalability for adaptation to varying network and resources at a reasonable complexity cost. As MPEG-2 is widely used today, we will use this sometimes in comparison with MPEG-4 results.

5.2 Streaming

There are basically two different modes of streaming possible:

- One-to-one streaming, using a dedicated, client-initiated connection (often TCP or RTP) between the transmitter and the receiver. This mode is commonly used for fixed video file (trailers and music videos) streaming over the Internet because of the individual access to the files and the already established HTTP connection of the user's PC to the Internet together with limitations due to firewalls. Because of its popularity, a lot of different protocols exist, some of them even using the HTTP byte-range sub-protocol for tunneling.

  This streaming mode makes most sense in the hot-spot scenario, where a one-to-one relation is desired. However, if a switchover between different display devices is required, or multiple receivers should be able to view the same transmission at the same time, the following mode is more suited.

- Multicast streaming, using an IP multicast address and UDP to broadcast the stream. For this mode, only very few different protocols exist. RTP (Real Time Protocol) provides just a simple wrapper around the elementary audio and video streams, and uses RTCP (Real Time Control Protocol) to control the dataflow. In general, the audio and video streams are not multiplexed, but just sent via different UDP ports to the same multicast address. This is in contrast to what other streaming formats do, as they use streaming container formats like ASF or so-called elementary streams like MPEG-2, which multiplex the audio and video streams and provide for mutual synchronization. The RTP stream receiver has to recreate the synchronization by using timestamps in the separate streams. In addition, the description and parameters of the stream must be sent along. This is either provided by using an additional protocol, RTSP (Real Time Streaming Protocol), or, sometimes, by distributing the description also via multicasting, as in the Mbone system. RTSP provides a control protocol for the client, allowing him to start/stop the actual stream and negotiate stream parameters like resolution and bitrate. RTP/RTCP is currently used as transport protocol for Real Media and Quicktime streaming, and Quicktime even uses the standardized RTSP.

If multiple concurrent receivers or a switchover from one receiving device to another (with different IP address)_is required, multicasting is the only possible option. It should be noted that with a simple broadcast network medium, like the bus structure of the original Ethernet or, on this case, wireless LANs, the load is the same with a single multicast session as with a single one-to-one connected session. Only in a switched network multicasting provides a heavier load on the complete network, since the UDP packets use multicast Ethernet frames, which have to be sent to all ports of an Ethernet switch. Even in this case, RTP streams can also be used with unicast addresses.

From a power management point of view, UDP provides the additional advantage that acknowledges and such does not necessarily need to be sent from the receiver to the sender, thus requiring no activation of the power-consuming transmitter.

The scenarios indicate that both one-to-one and multicast streaming as well as handovers will be taken into account within the BETSY project. The BETSY framework implementation will handle three (3) streams running simultaneously. This number is high enough to experience interaction and interference between applications and low enough for a practical implementation.

5.3 User-level Streaming Controls

According to the scenarios, there are the following user-initiated changes in the displaying of A/V streams:

1. The usual controls for volume, brightness, contrast, etc.
2. Switching of streams between display devices, e.g. from the larger wall display to a portable tablet
3. Changing the display resolution, either by switching between displays or from full view to PiP (Picture in Picture)
4. Switching input, like different DVB (TV) channels or media to play
5. For recorded streams (media files), pause/resume and fast/slow forward/reverse should be supported. In addition, live streaming could be enhanced by offering time-shift, i.e. seamlessly recording the real-time live stream and playing it with a (small) delay.

Some of these interactions have rather isolated consequences like volume and brightness, others are supported by the streaming mechanism like switching between devices via multicast, whereas others, though, have far-reaching implications, like on-the-fly switching of display resolutions and fast forward/reverse. The requirements and their implications on the implementation are explained in more detail in the following:

5.3.1 Volume, Brightness, etc

The adjustment of volume, brightness and contrast are the easiest to implement, as they only concern the video and audio rendering which takes place in the player device. The decoders produce for audio PCM data, which can be scaled and filtered to provide volume, treble, bass and stereo controls, and for video so-called YUV (i.e. luminance or B/W signal and chrominance of color signal) data, which already need to be converted by a linear transformation (matrix multiplication) to yield RGB data for the display hardware. Thus, image controls can be easily integrated in this processing step.

5.3.2 Switching devices and resolution

This is one of the heavier requirements. Switching the same stream between display devices does not pose problems if the same resolution is used on both devices and the stream is multicasted, as is usual for live streams. In this case, the old device disassociates from the stream by indicating a switch-over at the media center, such that the stream is not stopped but continues for a certain time, and the new device retrieves the necessary connection information from the media center and attaches to the running stream. In practice, this will probably require some extensions in the RTSP streaming server implementation.

A one-to-one stream can usually be switched off at the media center, by indicating the last timestamps of the processed media packets, and restarted from another device by retrieving first this resume-timestamp from the session manager of the media center, and then restart the stream at the streaming server with this timestamp as start time. In this case, the media center must provide the functionality to actively manage the states of the involved devices. It should be expected that the new device needs a few seconds (< 5s) to synchronize on the new stream.

Switching resolutions on-the-fly is more complicated, since it depends on the available bandwidth, the nature of the stream and on quality factors:

1. Is the available network bandwidth sufficient if switching from smaller to larger resolutions?
2. Does the media stream or file support or provide a higher or lower resolution?
3. Is it possible to transcode the stream to a lower resolution/bandwidth on-the-fly?
4. Is it possible or suitable to use the original resolution and interpolate a smaller one, like just displaying every second pixel for a QCIF to CIF switch?

Closely related to the manual selection of resolution is the restriction of choices in case of restricted bandwidth or energy on mobile display devices.

Basically, there are the following technologies available:

5.3.2.1 Media Stream Scalability

One possible solution based on stream or media support is to make use of MPEG-4's enhancement layers. The idea is to provide flexible video streams in three different dimensions:

1. Spatial scalability, that is the stream supports more than one display resolution,
2. Temporal scalability, by having the stream support different frame rates, and
3. SNR scalability, by supporting different qualities (signal-to-noise ratio, quantization accuracy) in the same stream.

Each of these three scalability dimensions can be implemented by providing a stream that is multiplexed of a so-called Base Layer (BL) and one or more Enhancement Layers (EL), providing either more quantization accuracy, additional frames or more resolution. A typical approach for the home scenario is to provide a movie stream with a BL of CIF resolution, a first EL that provides SDTV resolution, and perhaps a second EL improving the quality, thus switching from spatial to SNR scalability. An outdoor scenario could combine spatial with temporal scalability, by using a BL with QCIF and lower framerate, a first EL providing a higher framerate and, lastly, a second EL to achieve CIF resolution.

While enhancement layers have been already introduced for MPEG-2, they were mainly intended to provide both SDTV and HDTV resolution in same media file or providing prioritized network streams with high priority SDTV BL and a low priority HDTV EL. In addition, enhancement layers were usually confined to be an “all or nothing” solution, meaning that they must be completely processed with the base layer to achieve their effect. For network streaming, this seriously restricts the choice of bitrates for concurrent streams. Recently, the s-called Fine Granularity Scalability was added in the MPEG-4 Streaming Video Profile (SVP) [21], which enables continuous improvements instead of the discrete steps of additional enhancement layers by providing the mechanisms to produce an enhancement bitstream that can be partially used to enhance the resulting frames. In particular, the bitstream can be truncated into any number of bits within each frame to provide a proportional improvement, which means that a streaming server can transmit the enhancement layer at any bit rate without having to expensively transcode the stream.

5.3.2.2 Stream Transcoding

This refers to the re-processing of a stream to provide different resolution and/or framerates, with the aim to match a specific device's display resolution or to achieve a lower bitrate for bandwidth reduction or reduced energy consumption during decoding.

Transcoding means that the original stream is decoded into in-memory frames, which are then at the same time encoded into the desired destination format. Thus, different codec families can be supported (like converting from Microsoft WM8/9 to MPEG-4), different resolutions as also framerates can be produced. Obviously, this method is very CPU and memory consuming, and often is impossible to do in real-time. In our scenarios, only a well-equipped media center is able to accomplish this task.

5.3.2.3 Scaling, Interpolation and Frameskipping

If the required infrastructure for transcoding or the scalable media files/streams are not available, changes in resolution can also be achieved by scaling the decoded frames on the client into smaller display sizes or by interpolating the frames into larger display sizes. In this case, of course, no change in network bandwidth for the streaming is achieved.

Scaling usually would be used to shortly reduce the display area of a running stream, like for PiP (picture in picture). Interpolation is often used to display CIF or SDTV size streams on computer displays, which have higher resolution. If optimal scaling factors are used (powers of 2), performance is optimal.

5.3.3 Input and channel switching

When switching channels or input sources, the media decoders need to adjust to the new stream properties. In addition, for network streaming usually buffering is used to accommodate fast fluctuations of radio signal quality or available bandwidth. Therefore, the delay until the new source is displayed on the screen cannot easily be unnoticeably short. Anyhow, as experience has shown with digital satellite receivers, a delay of more than 1s for "zapping" from one channel to another is usually not acceptable and easily becomes a disqualifying factor in choosing a product.

5.3.4 Slow and fast motion, etc

Whilst it is rather easy for media players with "local" media files to provide typical VCR functionality like Pause, Fast and Slow Forward and Reverse, the fact that the media source in this case is a network stream requires considerable effort. Assuming that the streaming uses the ISMA (Internet Streaming Media Alliance) framework with RTSP (Real Time Streaming Protocol), RTP (Real Time Protocol) and RTCP (Real Time Control Protocol) as transport protocols and MPEG-4 as media format, the following options are possible:

- Pause and Resume are already provided by RTSP.
- Seeking/Skipping in the stream is possible by using the time spec (NPT) of RTSP in the DESCRIBE and PLAY commands.
- Fast/Slow Forward might be possible by using RTCP messages back from the client to the streaming sender, in effect "faking" a certain framerate. RTCP is used to control the packet rate of the streaming server on behalf of the client. This, of course, is only possible in one-to-one streaming scenarios, but not with multicasting. In fact, this functionality has not been seen in real implementations. Alternatives could be a more intelligent streaming server that already skips the necessary frames before sending them on the network.
- Fast/Slow Reverse is similar to the second alternative in the last item, as RTCP does not help here.

Consequently, in a streaming scenario the advanced functionality of usual VCRs is often only possible by considerable support of the streaming server, sometimes probably requiring protocol extensions. The ISMA specs currently do not support such functionality, which is not surprising as the main scope is that of Internet streaming with independent, dislocated servers and clients.

5.4 Stream Description Information

The actual streams need to be described in two categories:

1. Processing information, i.e. audio/video bitrate, frame resolution, audio channels, length, codec parameters, synchronization means, etc, and
2. Descriptive information or content meta data, like title, description, copyright, duration, in the case of movies even more detailed descriptions like category, list of character roles, director, producers, (unique) identification, option to reference or include reviews, etc.

While the processing information is due to its necessity already included in the streaming format (MPEG-4 descriptors), content meta data is often only partially available. In most cases, there are provisions of the file and streaming formats to transport the basic data like title, author/copyright, but there is few support for more structured meta data. Since this information is absolutely necessary to actively manage media streams, there are some standards available to provide a common data model for such content meta data:

1. MPEG-7 is a very comprehensive specification of multimedia content data, providing information models in XML of media sources, consumers, producers, the storage format, and the actual usage. It is aimed at providing the necessary information to automatically search, browse and filter entire media collections, to enable users to select their favorite movies depending on director, category, actors and so on.
2. TV-Anytime is closely related to MPEG-7, but has the restricted point-of-view of supporting the management and storage of broadcasted media on personal media recorders. This includes, e.g. electronic program guides (EPG) and personalized play lists, with additional functionality like referencing external content (additional plot descriptions and review) over the Web. In addition to data models in XML, it also describes a web-based API.
3. DVB Service Information, DVB-SI, is currently widespread in use by nearly all broadcasters of DVB programs. It predates MPEG-7 and TV-Anytime and its scope is just centered on providing content information on TV programs, serving to provide a simple form of EPG. It's EIT (Event Information Table) consists mainly of information about events (broadcasts), i.e. their time, title and description. In contrast to the former two standards, no additional information is conveyed, so categories, directors or actors are not explicitly modeled and can only be added to the so-called Extended Description, together with a summary (plot) of the event. Because of the lack of exact guidelines and additional structuring, some broadcasters tend to use wrong formatting in the available text fields, such that sometimes channel-specific fixes are necessary (cf. VDR, an open source DVB-based hard disk video recorder application).

While content information in DVB channels is standard, the use of MPEG-7 or TV-Anytime is not yet popular in consumer environments. Due to the fact that TV-Anytime is based on a subset of MPEG-7 with additional extensions, it seems to have the right scope and coverage to serve as guideline for the modeling of content meta data in BETSY.

5.5 Network reconfiguration

The scenarios both involve different, concurrent streams in a network (WLAN cell) that cannot provide enough bandwidth for all streams. Therefore, when changes in stream parameters (like switching from a smaller display device to a larger one) take place or an additional stream is required to play, the available bandwidth must be recalculated and the already active streams must be reduced in bandwidth (reconfiguration) or the request for a new stream must be denied or renegotiated with a lower bandwidth. Depending on the streaming sources, the involved entities/devices are:

- The media center, acting as the main media management of the house and likely to coordinate the media-relevant use of the WLAN,
    - The access point, which actually sets up network connections with a specified bandwidth and/or priority making use of the QoS extensions of IEEE 802.11e,
- Any other wireless networked device that is not using the media center as coordinator, but subject to the media access coordination of the access point,
- Possible devices creating interferences, like the microwave oven, DECT phones etc.

Depending on the network event, a reconfiguration involving 2-3 streams with different display devices and streaming servers can probably take some seconds until a stable bandwidth distribution is again reached. Provided that the event is a “managed” one, i.e. it is announced to a bandwidth coordinator (can be implemented centralized in the media center or in a distributed manner), the response time can surely be expected to be quite fast, since the media center’s streaming server can react by, say, readjusting the frame rate of an eligible stream or just by denying the new streaming request. This should happen in not much more than 2s. “Unmanaged” events, like a new device in the WLAN cell (e.g. the PSC of the guests or father’s laptop in the first home scenario), must involve both access point and the bandwidth coordinator, which can be expected to take some negotiation round-trips and, consequently, more time. Lastly, external events like interferences can be managed in several ways; fast bandwidth changes might be overcome by using scalable video formats alone. Longer time bandwidth changes can be managed by the access point or by feedback on the reception quality from the receiver to the transmitter (who then adjusts the bandwidth of the transmitted stream accordingly). Management by the access point will result in the reduction of bandwidth of all involved streams in the affected WLAN cell, while feedback between the receiver and the transmitter can directly deal with the reception quality per stream.

5.6 Wireless Networks

Based on the scenarios, we mainly have to deal with IEEE 802.11a/b/g networks. Most common are currently the 11g networks, and 11b can already be considered a legacy technology, since the prices of 11g equipment are almost as low as 1.7 times the 11b prices.

The adoption of 11a in Europe has been hampered by different regulations in the 5GHz band, which are (e.g. Germany) stricter than in the US. This has led to an additional specification, 802.11h, which adds TPC (Transmission Power Control) and DFS (Dynamic Frequency Selection) to 11a. Only equipment adhering to 11h is allowed to use transmission powers similar to 11b , while being used in out-door environments. Therefore, the market introduction of 11a/h equipment was delayed and cheap products have not been available, because the manufacturers were reluctant to produce special versions for the European market.

Since absorption of electromagnetic waves increases at higher frequencies, it is usually recommended to provide more APs for 11a networks because of their smaller range. On the other hand, 11a provides more non-overlapping channels (+12) than 11b/g (3-4), making their use in a more crowded environment (apartment houses) more suitable than 11b/g, where sometimes the interferences in, say, student dormitories, are becoming annoyingly strong.

There seems to be the consensus that 802.11e (WiFi QoS) compliant products or at least firmware updates will be available not sooner than the end of 2004. Since it is expected that only very recent WiFi modules/chip sets will support 11e, care should be taken to select the proper products that can be upgraded accordingly. The industry currently uses the term WMM (WiFi Multimedia) for a subset of 11e, and WME (Wireless Multimedia Enhancements) will be used as brand name for certification.

In order to evaluate the bandwidth fluctuations of the wireless networks, the various packet filter, firewall, bridging and traffic control options of Linux might favorably help to simulate a loaded wireless network, by using a dedicated Linux PC as router or bridge.

5.7 Power Management

The goal of power management in system design is to reduce the amount of energy required for a specific task, which is either limited in time or has a periodic nature. There are basically two ways to accomplish this goal:

1. On/Off or Run/Idle: Keep the system running as long as the task requires it, and then shut the involved components down. In addition, keep only the required components or functional blocks running.
2. Adjust the required power by reducing supply voltage and/or clock frequency.

Power consumption in digital CMOS circuits is basically composed of static terms and dynamic terms, which depend on the operating frequency. The static terms are the so-called leakage power, based on the reverse bias current of parasitic diodes in the chips, and standby power that needs to be present to maintain standby functions and analog circuits. The dynamic terms are composed of the short-circuit power, occurring when inverter circuits switch state and both NMOS and PMOS transistor are shortly switched on, and the major part, the capacitive switching power. This power results from the charging and discharging of MOSFET gate input capacitances, and is proportional to the switching frequency and the square of the supply voltage:

$$P_{dyn} \approx V^2_{dd}\, f$$

Consequently, the most gain in reducing power consumption is reached by reducing primarily the supply voltage and, secondly, the frequency of the master clock. However, the voltage cannot easily be reduced without also reducing the switching frequency, because the circuit's timing becomes unstable. In addition, the prevalence of dynamic power consumption means that shutting down components can easily be achieved by just switching off their clock lines. In practice, both approaches are used: Peripheral or specialized components can be switched off through gated clock lines, forming so-called clock domains, while central components like CPU cores can have their supply voltage and clock frequency adjusted.

A typical example of applied power management can be found in contemporary CPUs for mobile devices, like laptops, PDAs or smart phones. Intel has recently introduced the Wireless SpeedStep technology [22] for its new XScale processors. The PXA 27X processor has six different operating modes, ranging from normal over idle, deep idle, standby to sleep and deep sleep mode. Many of the functional blocks of the processors chip, like the CPU core, the memory controller (for external SDRAM chips), the LCD controller, GPIO etc. have their own power domains with external supply pins. Therefore, these blocks can be supplied with voltages and partly also be switched off in standby and sleep modes.

Table 7 CPU core power consumption with several loads

Frequency Point @ voltage V	Dhrystones 2.1 Current (mA)	Power (mW)	MPEG4 Decode current (mA)	Power (mW)	Power Stress Test Current (mA)	Power (mW)
624 MHz 1.55 V	658	1019	622	964	1006	1559
520 Mhz 1.45V	503	729	475	689	767	1112
416 MHz 1.35V	395	533	420	567	594	802
312 MHz 1.25V	297	371	333	416	436	545
208 MHz 1.15V	208	239	263	303	295	339
NOTE: Core Frequency shown above/Internal bus = 208MHz/Memclk = 208MHz/SDCLK = 104MHz						

External to the actual CPU a so-called PMIC (Power Management IC) provides the variable CPU core voltage. This is a switching power supply and is controlled by I2C from the CPU, whereby PMIC can be ordered to perform controlled smooth changes of the core voltage. The core's clock frequency is controlled through integrated PLL circuits that generate the desired frequency from an external reference (quartz). Similar processor enhancements, e.g. power domains and voltage/frequency scaling, are or will soon be available for other embedded high performance CPU families. The effect can be seen in Table 7, which shows the CPU core power consumption with various processors loads (benchmarks) and frequency/voltage combinations:

As can be seen, the introduction of discrete operation modes together with voltage/frequency scaling allow the adjustment of power consumption in both coarse and fine granularity. The discrete operation modes allow for optimal switching between standby, idle and run modes depending on the actual task, whereas voltage/frequency scaling allows for exact tuning of the CPU speed for periodic tasks with deadlines while minimizing at the same time the supply voltage. In order to show the intended improvements in power consumption, the use of energy saving operation modes with selective shutdown and voltage/frequency scaling are the most important mechanism that must be available. Therefore, the hardware platform for the mobile devices should definitely support these.

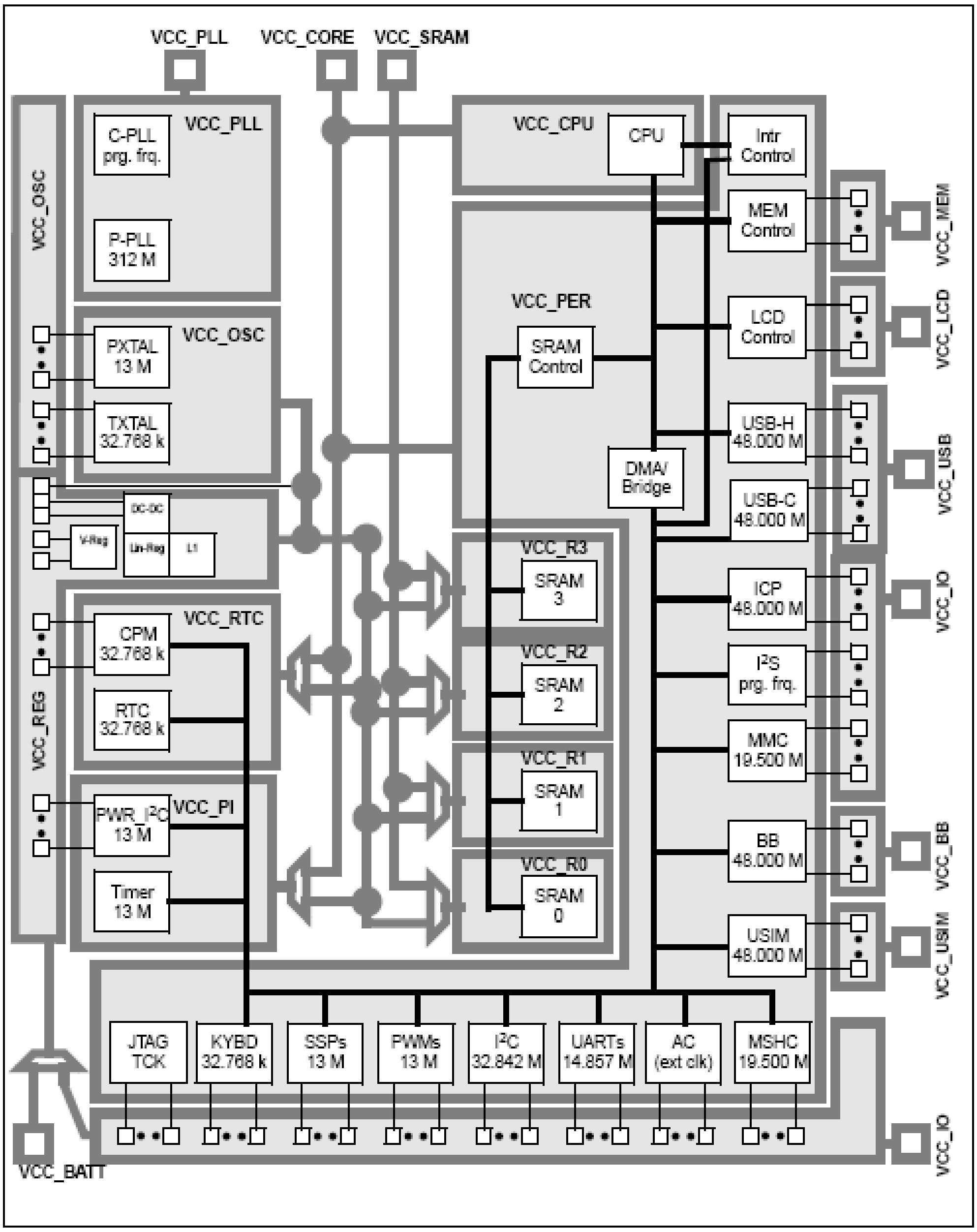

Figure 6 Power domains of XScale 27X [23]

5.8 Mobile devices

According to the scenario definition, the mobile (display) devices involved should provide the following characteristics:

1. Display size of 320x240 (QVGA) minimum, for SDTV a VGA resolution (640x320) is preferred.
2. Wireless connectivity, either by integrated WiFi module or external interface, like PC-Card or CompactFlash (CF).
3. Audio subsystem for input and stereo output (usually AC97 based).

4. Exchangeable storage media for multimedia content, like CF or SD (Secure Digital) cards or even CF II Microdrives.
5. Sufficient battery capacity for 2 hours continuous media playing.
6. For the hot spot scenario, a digital camera or at least an interface with a suitable resolution and frame rate must be available.
7. A hardware platform and operating system open enough to provide access to power management facilities.

Somewhat related to these requirements are those pertaining to the software aspect of the platform, i.e. the operating system.

5.8.1 Display

Usually, portable devices and PDAs nowadays have typical screen sizes of 320x240 with a color depth of 16bpp and diameter of about 3.5”. Recently, larger displays became available for top-class PDAs with 640x480 pixels and 4” diameter, not only for PDAs, but also for portable DVD players, which usually have even larger displays of 5” to 7”. Since the LCD interface drivers are usually integrated in the processor, the available options (pixel depth) are limited. The PXA 27X, for example, supports 16, 18 and even 24bpp, but the latter only with an 8bit interface, because of a lack of suitable LCD driver pins.

Most common are transmissive displays, which use an active backlight to provide bright enough displays. The backlight is usually realized as cold-cathode fluorescent lamps (CCFL), requiring voltages in the 1-2 kV range, which are generated by dedicated so-called inverter modules. Consequently, the backlight consumes a considerable amount of power, about 500-1000mW, depending on the display size.

Because backlit display most provide a large brightness and, accordingly, consume a lot of power in outdoor environments, a combination of the passive-lit reflective and the active-lit transmissive displays was developed, the transflective displays. They use a partially reflective coating on the rear side, which allows switching off the backlight in bright environments. Still, the image is not as good as with a bright backlight, but consumes only about 60% of the power a transmissive display uses, e.g. 350mW for 3” display.

5.8.2 Wireless Module

While integrated modules are probably better integrated in the power management system, they also severely restrict the choice of 11a/b or g WLAN equipment. Current PDAs usually provide at most 802.11b. With respect to the power management capabilities of the wireless module, these should fulfill at least one (or more) of the following requirements:

a) capability to participate in a system-wide DPM (Dynamic Power Management) policy, by offering a selective shutdown / power-up of the whole module

b) implementation of the 802.11 MAC-level power management features (Active/Awake and Doze/Power Save modes, TIM / ATIM elements support),

c) implementation of the 802.11 PHY-level local power management features (set/get the power level of the local transmitter), or

d) implementation of the 802.11h Transmission Power Control (TPC) features (MLME.TPCADAPT service) to adapt a peer’s transmitter power level.

5.8.3 Audio

There are two common interface alternatives for the audio subsystem: AC97, coming from Intel’s PC design specifications, and I2S (Inter IC Sound bus) by Philips. Both use a synchronous serial bus to separate the digital from the analog domain, which is important to minimize interferences from digital transients. Both interface are bi-directional, providing for input sampling and D/A output conversion by external CODEC devices.

5.8.4 External Storage Media

A portable media player should, beside network streaming, also support portable storage media. Popular types of storage are:

1. CF (Compact Flash) cards. Compared to the other choices, they are quite large, but the larger CF II slots allow the use of micro drives with a 1"diameter, which store up to 4GB of data, which would allow for several movies in MPEG-4. CF uses a parallel interface, almost identical to the IDE hard disk interface.
2. SD (Secure Digital) and MM cards use a single bit or 4bit (SDIO) interface and have about half the size of a CF card. Because of this size, they are increasingly used in PDAs and provide capacities of up to 512MB-1GB are comparable read/write speeds as CF cards.
3. Memory sticks are typically found in Sony products, uses a bit serial protocol and, thus, have a smaller speed than SD or CF cards. Their capacity is slightly smaller.

In most cases, their interfaces are supported by integrated serial communication controllers, or can be emulated by GPIO signals.

5.8.5 Battery capacity

This is one of the most crucial factors. Depending on the actual market positioning of a wireless portable media player, a run time with a single battery charge of at least 2-3 hours (i.e. the length of longer movie) must be achieved. Smaller devices, with PDA-like displays, could be constrained to shorter run times.

The current rechargeable battery technology uses lithium-ion or lithium-ion polymer technology, which yields the highest energy density. The polymer variant has the advantage of providing very flexible form factors, but is still not yet mature. Lithium-ion cells have delicate charge and discharge properties, since even a slight overcharging or a deep discharge permanently damages the cell. Due to this reason, manufacturers provide no single cells but only battery packs with integrated charge controllers that communicate with a serial (like I2C) with the actual charging block in the device's power supply. The high energy density also means that accidental shorts will easily generate so much heat that the cells might explode – which has in the past already happened in consumer products. Therefore, Li-ion cells require special cell cases that provide security valves, adding space and weight. Contrary to Ni-Cd or Ni-MH cells, the voltage of Li-ion cells does not remain as constant and varies from 4V down to 3V.

PDAs use battery packs with 3.7V and a capacity (C) from 1000-2000 mAh. The capacity is usually calculated to be used with a discharge (load) current of 0.2-0.3 C, thus providing a lifetime of 3-5 hours. This means that about 1-2W of continuous battery power.

5.8.6 Digital Cameras

A typical small digital CMOS camera (which have a lower power consumption than the older CCD types) provides a QVGA (320x240) at 60 frames per second or VGA image at 30fps. It is usually interfaced by a 4 or 5bit synch. serial interface, using a 6 or 12 MHz pixel clock and 8 or 10bit per pixel [24]. This results for VGA in 12-15Mbyte/s, which clearly indicates that a dedicated controller should be used to interface such cameras to the CPU. The XScale PXA 27X has such an integrated controller, but there are also external video processors available, which are used in web cams and provide JPEG (and M-JPEG) compression with video processing (noise filtering, sharpness enhancements) and 8bit parallel host interfaces with FIFOs.

5.8.7 Hardware/Software platform

For the purpose of providing a real demonstrator device as also for the development and evaluation of the BETSY framework, there are basically two choices for the hardware platform:

1. Use an evaluation board that already has the required hardware either on-board or the interfaces to use external devices like CF and PCMCIA/CardBus slots for WLAN cards, fast parallel and serial interfaces for cameras, LCD and storage devices and so on, or
2. Use a suitable commercial product like a PocketPC 2003 PDA with suitable equipment like digital pocket camera for CF slots, integrated WLAN adapter, large enough display and so on.

Taking into account that the BETSY framework will need access to the device's power management and to control the scheduling of tasks (network stack, MPEG codec, display driver, application control, etc), only open systems are eligible. This precludes devices like portable multimedia player (e.g. iPod, Archos AV 320 and 4X0) and portable DVD player, as they are embedded devices without any (open) access to the operating system.

The technical requirements for the operating system make Linux an attractive choice, since there is a considerable activity for the more popular processors for mobile devices, like StrongARM and XScale, and for commercial use the lack of royalties and the versatility for new uses/applications/enhancements is a strong advantage.

Most evaluation boards for XScale processors provide so-called Board Support Packages that support Microsoft Windows CE as also some embedded Linux distribution. The disadvantage with such boards is that it is not clear if a specific configuration of hardware works together, the additional amount of customized drivers or even having to write drivers from scratch, and in general the problem of possibly having to design custom hardware.

PDAs, on the other hand, provide a well-integrated hardware and software platform, but only for their native operating system, i.e. PocketPC with WinCE 4.X. There are existing ports of Linux for some PDAs, but the support of manufacturers is very often not existing at all or only sporadic, like Compaq's contribution for the original IPaq. While the designs can rely on the well documented XScale processors with their main integrated controllers for LCD, audio, power management, many of the device-specific components like touchpads, additional buttons, memory address map etc. are unknown and may change easily from one model to an other, even from the same manufacturer. Since many PDAs are rather OEM designed, it is not surprising that even devices from brand names often differ enough to make the task of porting Linux are long and cumbersome one – and there is often few hope of getting access to hardware documentation. In this respect, even PDAs can be considered 'closed devices'.

Anyhow, taking into account the requirements on display size, wireless adapters and external interfaces, speed and CPU enhancements for media processing (e.g. Intel Wireless MMX), recent business PDAs with WiFi and Bluetooth, large VGA-size displays and the recent XScale PXA27X processor look very interesting.

Quoting some reviews form the Internet, typical products falling in this selection are:

- HP iPAQ hx4700 – released 26/7/2004

This is a business oriented PDA. The model uses the most powerful Intel's processor a 624MHz Xscale PXA270 and takes advantage of the two technologies that come with this PXA family: the Speedstep and the wireless MMX technology. It has a high-capacity lithium-ion user replaceable battery and plenty of memory (total of 135MB user-accessible memory). Wireless connectivity comes through Wi-Fi and Bluetooth. In general the wireless connections, based on experts' reviews, are characterized excellent. The operating system provides landscape and portrait orientations. The 4-inch VGA screen is very bright and sharp. The cost is $650.

- ASUS MyPal A730

It's one of the first pocket PCs with native support for VGA resolution and runs windows 2003 SE that adds support and features screen rotation to landscape on the fly (3rd party software add-ons are not necessary). Connectivity is achievable through USB cable. USB host can be enabled/disabled through ASUS System Settings applet. 45.45 MBs of RAM are available to user while other models offer that amount or a bit less. Through the System Settings Control Panel applet the user can set the processor speed to turbo, standard or power saving mode. For Bluetooth 1.4.1 it uses Widcomm's driver. The battery has a lifetime of about 2 hours in full charge operation. Available at the end of September 2004. According to user's opinions 3rd party camera software for improved shot quality is needed.

- Dell Axim 30

Perhaps the most significant change of that model is the move to the latest version of the pocket pc operating system. This the first handheld to come out with a chip this fast 624 MHz while the 64MB RAM is available to the user. It offers both Bluetooth and Wi-Fi (802.11b) connectivity, but only the standard QVGA display size (320x240). The X30's Wi-Fi range is quite good because of the included antenna. The latest version of the windows had simplified the process of getting connected to a Wi-Fi AP. The Bluetooth isn't as fast as Wi-Fi but it's acceptable in getting your email and surfing pages that have been designed for mobile devices. The cost for the 312MHz processor model is $280 and with no wireless connectivity it costs around $199.

- FUJITSU SIEMENS LOOX610BT/WLAN

The good features of this model are 128MB RAM (110 available to the users), dual wireless, dual expansion slots, decent battery life, speed, an excellent third party software bundle, useful OS software add-ons, large user accessibility ROM storage. The Loox 610 is both long and wide while it does not offer a voice-recording button. The included USB cradle utilizes a separate USB sync cable (can be used when traveling). It includes IrDA, Bluetooth, Wi-Fi but the Bluetooth setup manager is a bit confusing and very slow when turning on/off and the Wi-Fi reception is sub-par despite the external antenna. In general the connectivity is excellent but the wireless implementations are poor.

Concerning the availability of a Linux port for these models, it seems that the more popular models are more likely to attract enough active Linux developers to provide a useable port in a reasonable time, say about 6-9 months. Therefore, the iPAQ HX 4700 because of its brand name, the Dell because of its good price/performance ratio and perhaps the Loox in Europe might be hopeful candidates.

Based on this limited list, the final decision on the hardware and software platform will only be made at the start of WP4, in order to take the latest developments (wrt. Availability, popularity …) at that point in time into account.

6 Conclusions

This document described the main scenarios for the BETSY project divided over the home environment and a hot spot. After an introduction on home network and hot spot technology in chapter 2, chapter 3 and 5 describe the scenarios. The scenarios are written from a consumer-oriented perspective. The technical requirements are derived in chapter 5, limiting the scope of the project, but still including the important aspects for our research. We have written down detailed requirements for the network, the mobile devices involved and the coding characteristics of the content in our scenarios. Main conclusions are that the BETSY focus will be on 802.11a/b/g networks, point-to-point and multicast communication, including handovers. A maximum number of three video streams at the same time within one AP are considered. Special attention will be paid to the timing requirements in the case of user input that leads to changes in the number of streams or reconfiguration of existing streams. For the video coding format certain specific types of MPEG-4 scalable coding, sometimes compared with the currently popular MPEG-2 format.

For the mobile devices we will only take into account devices, which have the possibility of doing power management, as energy reduction is one of the project goals. The power management system can be in the form of adjusting supply voltage and/or clock frequency or switching off system components when they are not active.

Last but not least, several possible hardware/software platforms to do the verification of theoretical results are investigated, but the actual decision which platform to use will only be made at the start of WP4, in order to take the latest developments into account.

This document does not describe specific requirements from the application/system designer point of view. The BETSY framework that will be developed, will be general enough to provide the designer the possibility to make trade-offs between QoS, timing aspects and energy and as such help to reduce the length of the design process as well as to analyze the impact of new applications/features in a much earlier design phase.

The requirements derived, will be used as input to WP2 and WP3, defining their playground, while we will iterate and finally implement (a part of) the scenarios defined in this document in WP4. The scenarios will also be used to validate the proposed solutions later.

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