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XtreemOS

Integrated Project
BUILDING AND PROMOTING A LINUX-BASED OPERATING SYSTEM TO SUPPORT VIRTUAL ORGANIZATIONS FOR NEXT GENERATION GRIDS

Virtual Organization Basic Requirements and Specifications for Mobile Devices

D2.3.1

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Executive Summary

This document reflects the first steps in the development of XtreemOS for Mobile Devices (XtreemOS-MD), a Linux-based operating system enabled to operate in Grid environments as part of a virtual organization (VO), and able to run on a mobile device. More concretely, this document belongs to WP2.3 activities, covering the Foundation layer (called XtreemOS-F) that will be embedded in the operating system itself, to support basic VO and Grid functionalities. Thus, the goal of the document is to provide a first specification of the hardware and network requirements that mobile devices must fulfil to host this XtreemOS-MD operating system.

After analyzing the state of the art in mobile devices and mobile Grid computing, we have presented hardware and network requirements for virtual organization support in XtreemOS-F for MDs. It has been assumed that laptops will have enough capacity so as to be able to run the standard version of XtreemOS. Therefore, we will focus our efforts on personal digital assistants (PDAs) for the basic version of XtreemOS-MD, and smartphones for the advanced version. Due to their limited capacity, mobile devices will be treated as special nodes, and will generally act as resource consumers rather than providers.

This document, together with deliverable D2.3.2 (*"Requirements and Specifications of a Basic Linux Version for Mobile Devices"*), will constitute the input to the design of a basic Linux version for mobile devices (task T2.3.3).

As stated earlier, basic version of XtreemOS-MD will support PDAs, while advanced version will work on smartphones too. This has a technological as well as a market reason, as PDAs are currently more stable platforms for development, and Linux in those devices is more mature. Also, the lapse of time between basic and advanced versions of XtreemOS-MD will allow Linux smartphone initiatives to become more focused and clear.

PDA market, although composed by lots of manufacturers, has only one clearly outstanding hardware architecture. ARM (Advanced RISC Machines) accounts the 75% of all embedded devices worldwide (particularly, the XScale family of processors). Obviously this has been translated into one of the specifications: ARM architecture must be supported by XtreemOS-MD.

Other important feature for MD to be an operative node in a Grid oriented OS, like XtreemOS, is connectivity or network interfaces. IrDA, Bluetooth, WiFi, GPRS are widely spread, although not all of them will be equally useful for mobility scenarios, due to their range and bandwidth.

Mobile IPv6 will be the path to follow in the future, according to current research and development efforts in the area of mobility. XtreemOS-MD will make use of Mobile IPv6 in order to implement terminal mobility, allowing a mobile node to maintain its connectivity when moving from one access point to another.

In the field of mobile Grids, the most important research effort is represented by the Akogrimo project. The architecture and results of this EU-funded project are studied in the document, although theirs is still a work-in-progress.

Another relevant EU-funded project, Daidalos, has made much progress on enabling context awareness and service pervasiveness using Mobile IPv6 and hence is also studied, as our activities can benefit from this project's results.

In order to predict the needs and requirements of XtreemOS-MD, which is on an early stage of development, we draw from hardware and network-related requirements from the reference applications as well as requirements derived from the state of the art in mobile devices, mobility and virtual organizations.

Afterwards, hardware and network requirements for XtreemOS-F for Mobile Devices have been elicited. These requirements take into account the fact that XtreemOS-MD should be able to run on the most common hardware devices available on the market, allow users an easy interaction with the operating system and support VO integration and management. Requirements from XtreemOS reference applications (D4.2.1) that affect this workpackage have also been discussed.

All those requirements have been translated into MD specifications, classified by importance. The most important basic specifications, those needed to be met by MDs to execute XtreemOS-MD in its basic version, can be summarized to a MD with an ARM processor, a minumum screen resolution of 320x240 and support for MIPv6 on a WiFi network interface.

Contents

Glossary

ARM	Advanced RISC Machine
BVO	Base Virtual Organization
CF	Compact Flash
CN	Correspondent Node
CPU	Central Processing Unit
DSL	Digital Subscriber Line
ELFIPOLE	Software chain performing acoustic wave propagation simulation (XtreemOS reference application)
EMS	Execution Management Service (Akogrimo Project)
EUChinaGRID	Interconnection & Interoperability of Grids Between Europe and China
EU	European Union
FMIPv6	Fast Handovers for Mobile IPv6
GPE	GPE Palmtop Environment
GPRS	General Packet Radio Service
GPS	General Positioning System
GSM	Global System for Mobile Communications
HA	Home Agent
HIP	Host Identity Protocol
HI	Host Identifier
HLA	Real time simulation communicating through the HLA middleware (XtreemOS reference application)

HMIPv6	Hierarchical Mobile IPv6
HP	Hewlett-Packard
HSDPA	High-Speed Downlink Packet Access
HSPA	High-Speed Packet Access
HW	Hardware
IEEE	Institute of Electrical and Electronics Engineers
IETF	Internet Engineering Task Force
IO	Input/Output
IP	Internet Protocol
IPC	Inter-Process Communication
IrDA	Infrared Data Association
JOBMA	Job Monitoring and Management Application (XtreemOS reference application)
JRE	Java Runtime Environment
LAN	Local Area Network
MAC	Medium Access Control
MAP	Mobility Anchor Point
MD	Mobile Device
MDVO	Mobile Dynamic Virtual Organization
MIPS	Microprocessor without Interlocked Pipeline Stages
MIP	Mobile Internet Protocol
MMC	MultiMedia Card
MMS	Multimedia Messaging Service
MN	Mobile Node
OGF	Open Grid Forum
OPIE	Open Palmtop Integrated Environment
OS	Operative System

OpVO	Operative Virtual Organization
PAN	Personal Area Network
PC	Personal Computer
PDA	Personal Digital Assistant
PIM	Personal Information Management
RAM	Random Access Memory
RFC	Request For Comments
RIM	Research In Motion
RISC	Reduced Instruction Set Computer
SCTP	Stream Control Transmission Protocol
SD	Secure Digital
SIMEON	Simulation of energy generation planning (XtreemOS reference application)
SIP	Session Initiation Protocol
SLA	Service Level Agreement
SMS	Short Messaging Service
SPECWEB	SPEC benchmark for evaluating the performance of www servers (XtreemOS reference application)
SRC	Secure Remote Computing (XtreemOS reference application)
TCP	Transmission Control Protocol
TEKES	Finnish National Technology Agency
TID	Telefónica I+D
TIFON	Messaging Application (XtreemOS reference application)
UDP	User Datagram Protocol
UFIR	Ultra Fast Infrared
UMTS	Universal Mobile Telecommunications System
VO	Virtual Organization
VoIP	Voice over IP

W-CDMA	Wideband Code Division Multiple Access
WAN	Wide Area Network
WAP	Wireless Application Protocol
WISS	Virtual Presence Application (XtreemOS reference application)
WLAN	Wireless Local Area Network
WPn	Workpackage n
WiFi	Wireless Fidelity
WiMAX	Worldwide Interoperability for Microwave Access
WirelessMAN	Wireless Metropolitan Area Network
XtreemOS-F	XtreemOS Foundation
XtreemOS-MD	XtreemOS for Mobile Devices
ZEPHYR	Solving of a 2 dimensional nonlinear unsteady viscous Bürgers equation (XtreemOS reference application)

Chapter 1

Introduction

The number and types of mobile devices that appear in the market grows every year. Nowadays we not only have laptop or tablet PCs, but also personal digital assistants (PDAs), advanced mobile phones (the so-called *smartphones*), portable media players, and even futuristic “wearable phones” and “nano-PCs”.

As XtreemOS is a grid-enabled operating system (OS), it would make no sense trying to fit the operating system in devices without networking capabilities, like portable media players. On the other hand, the most powerful mobile devices (laptops and tablet PCs) are so close to desktop PCs in regards of functionality and architecture, that we expect them to run the standard version of XtreemOS.

The aforementioned constraints suggest that we should focus mainly on two kinds of devices: PDAs and mobile phones. Regarding mobile phones, and taking into account the networking capabilities and processing power that XtreemOS will need, we will consider only medium- to high-end models (smartphones).

In a first approach to the XtreemOS flavour for mobile devices (XtreemOS-MD), we will only consider PDAs. The reasons for this decision are multiple; in the first place, its market is much more stable and mature, and less prone to sudden changes of direction (as its primary market has always been business and corporate clients), which could render XtreemOS developments obsolete even before they are finished. Secondly, the use of Linux in this kind of devices (either by manufacturers and communities) has a longer tradition and, as a consequence, their hardware has better Linux support. Also, these devices currently have more features and processing power than smartphones, so they are more adequate for a basic version of XtreemOS-MD.

1.1 Laptops as mobile devices

Laptops, although less portable than PDAs or smartphones, have been traditionally considered mobile devices. But we must note that, from an operating system point of view, they are basically identical to standard PCs, share the same architectures (x86 and 64bit) and in that regard, we are not targeting them in XtreemOS-MD, which will cover more resource constrained devices (such as PDAs and mobile phones).

Nevertheless, to take advantage of laptop mobility within XtreemOS, what we propose is to also port any mobility enhancements developed in XtreemOS-MD, to the standard version of XtreemOS (at least, as some kind of optional package that users can install/activate if they plan to be on the move, to get the same mobility advantages as other mobile devices).

1.2 Methodology

As it would be impossible to make a complete and detailed hardware specification for a system that is in its early stages of development, our approach has been to make a first draft of these requirements. For this, we have taken into account the latest technologies in mobile devices, and the most reliable source of information on how XtreemOS will be once it's finished: the requirements that it should meet.

It is also important to note that this document will be updated later, once other workpackages in XtreemOS (i.e. WP2.1 on VO support, or WP3.5 on security) provide more detailed frameworks and methods of operation, which could impose tighter requirements on mobile devices to be "XtreemOS-compliant".

1.3 Document structure

This document is structured as follows:

In chapter 2, we briefly describe the state of the art in mobile devices, concentrating on PDAs and their most common hardware and network features, and gather the most probable and accepted future trends in the area. In this chapter we also give a brief review on the state of the art in mobile Grids, virtual organizations and mobility in general.

Chapter 3 details hardware and network-related requirements to be met by XtreemOS-F for mobile devices, which are derived both from XtreemOS applications (WP4.2) and from the state of the art and previous research in the field of mobility and Grid. These requirements are currently the best source for extracting what kind of features will be needed by mobile devices to support virtual organization features provided by XtreemOS.

In chapter 4, and using the requirements as a starting point, the hardware and network specification for mobile devices to support XtreemOS-MD is given.

Chapter 5 draws the main conclusions to be derived from this document, and chapter 6 anticipates the next steps that are needed towards the construction of XtreemOS-F for mobile devices.

Chapter 2

State of the Art

2.1 State of the Art in Mobile Devices

In this section, we will focus on the PDA market, both current and foreseeable (although some mention to smartphones will be unavoidable). This will allow us to set feasible hardware and network requirements for mobile devices to run the basic version of XtreemOS-MD. A brief review about Linux OS in PDAs will also be done (although more detail will be provided in deliverable D2.3.2, which deals with the software requirements), as XtreemOS will be based on Linux. Additionally, we will review future mobile device trends, how they can affect XtreemOS, and the strategies that we will follow to deal with them.

2.1.1 Market Research

The most noticeable feature of current market research on the subject of PDAs, is that the fine line that distinguishes PDAs from mobile phones is rapidly blurring, as PDAs incorporate phone call features, and smartphones take over much of the functionalities traditionally performed by PDAs, like Personal Information Management (PIM), e-mail reading or browsing. Some studies consider phone calls to be the distinguishing feature, while others base their classification on the number of hands required to operate the device. Thus, the precise figures on market share can be quite incoherent between studies. In any case, our aim is not to make a thorough study of the PDA market, but just to draw a general picture that can help us when defining requirements and specifications.

According to [25], 4.5 million PDAs were sold in the third quarter of 2006. In this section we will review the most common features of these devices, including manufacturers, architectures, network capabilities and other important features.

In general, the number of PDA shipments and new models is stable or growing slightly, mainly thanks to the appearance of "connected PDAs", be it either with mobile phone capabilities or wireless connectivity. Other kinds of PDAs are decreasing in number, and will soon make a residual amount of the total number of PDAs.

2.1.1.1 Manufacturers

The results of market research are specially inconsistent regarding manufacturers' results, as the concepts of PDA and smartphone are no longer clearly distinguished. In general terms, and according to [25] and [18], the main players are:

- **Hewlett-Packard (HP)**
- **Research In Motion (RIM)**
- **Palm**
- **Mio**
- **Dell**

Of course, the goal of XtreemOS-MD should be to remain as brand-independent as possible, although some manufacturers seem to be more inclined to "open" the specification of their devices to the public than others (because of commercial interests and/or bound by contract not to do so). This openness really makes a difference when trying to install Linux-based operating systems in them (see section 2.1.2), and should be taken into account when choosing a device fit for XtreemOS-MD.

2.1.1.2 Hardware Architectures

Unlike desktop or laptop PCs, largely dominated by the x86 architecture, PDA manufacturers have chosen from a number of hardware architectures to build their devices, from MIPS to x86. However, the most popular architecture in PDAs and smartphones (accounting for over 75% of all 32-bit embedded CPUs [4]), is the Advanced RISC Machines (ARM) architecture. Particularly prominent, in the newer models, is the XScale family of processors, a variant of the ARM architecture.

2.1.1.3 Operating Systems

In regards to the operating system of mobile devices, again a wide variation across studies can be noticed, depending on which devices are counted as smartphones or as PDAs. In any case, the major options seem to be [25, 18, 27]:

- **RIM** for the Blackberries: owned by Research In Motion.
- **Palm OS**: owned by PalmSource.
- **Windows Mobile** (Pocket PC): based on Windows CE kernel, and owned by Microsoft.
- **Symbian OS** (specially in smartphones): owned by Nokia, Motorola, Panasonic, Samsung, Siemens and Sony Ericsson.

- Various operating systems based on the **Linux** kernel. This includes companies (MontaVista, Trolltech) and communities (Familiar, GPE, OPIE).

All in all, as XtreemOS will be based on Linux, our decision in this regard is already taken. However, the growth of Linux-based devices in the PDA and smartphone market (specially the Asian market) is quite noteworthy, and supports this decision.

2.1.1.4 Networking Interfaces

The market for PDAs which *cannot* be connected to a network is falling so fast that soon they will represent only a minute amount of these devices. In fact, most of the perceived utility of PDAs is gravitating towards voice and data communications. As a result, manufacturers are including more and more networking functionality in their devices. The most common are:

IrDA The Infrared Data Association (IrDA) defines physical specifications, communication protocols and standards for the short range exchange of data over infrared light, for uses such as personal area networks (PANs). In the case of PDAs, they are mostly used for connecting to a desktop PC, for data exchange (i.e. syncing contacts and addressbooks). It has a very short range (less than 1 meter), its speed goes from 2.4 kbps to 16Mbps, and it works best when the transmitter and receiver are in line of sight. The UFIR (Ultra Fast Infrared) protocol is also under development. It will support speeds up to 100 Mbit/s.

Bluetooth Bluetooth is an industrial specification for wireless PANs, probably the most widely used nowadays for this kind of networks. Bluetooth is a radio standard and communications protocol primarily designed for low power consumption, with a short range (power class dependent: 1 meters, 10 meters, 100 meters) based around low-cost transceiver microchips in each device. It is ideally used for communicating devices in close vicinity (although they do not have to be in line of sight of each other), which do not need high bandwidth (Bluetooth 2.0, the latest version of this protocol, reaches 2.1 Mbps). The main advantage of Bluetooth is its ease of setup and use, but it is quite limited in terms of range and speed, compared to other wireless interfaces like WiFi (see below).

WiFi (IEEE 802.11) WiFi (also Wi-Fi, wifi, etc.) is a brand originally licensed by the WiFi Alliance to describe the underlying technology of wireless local area networks (WLAN) based on the IEEE 802.11 specifications. It was developed to be used for mobile computing devices, such as laptops, in LANs, but is now increasingly used for more services, including Internet and VoIP phone access, gaming, and basic connectivity of all kinds. Extensions to this standard are under development and will allow WiFi to be used by cars in highways in support of

	802.11a	802.11b	802.11g
Operating Frequency	5 GHz	2.4 GHz	2.4 GHz
Bandwidth (typ/max)	25/54 Mbps	6.5/11 Mbps	24/54 Mbps
Max. users per access point	64	32	64
Coverage Range	50 meters	100 meters	100 meters

Table 2.1: WiFi standards 802.11a/b/g

an Intelligent Transportation System to increase safety, gather statistics and enable mobile commerce (IEEE 802.11p).

Table 2.1 shows the most common WiFi standards and their bandwidth, coverage range and operating frequency.

WiFi is one of the most used wireless networking technologies, either at home or in business and academia. It is also one of the most commont network interfaces included in PDAs, that make connection to a LAN or WAN possible, unlike IrDA or Bluetooth, which are more directed towards communication with one host (i.e. a desktop PC).

GSM/GPRS As mobile phone features are added to modern PDAs, this kind of radio interfaces are becoming more common. General Packet Radio Services (GPRS) is the mobile data service available to users of the Global System for Mobile Communications (GSM). GPRS can be utilized for services such as WAP access, SMS and MMS, but also for Internet communication services such as email and web access. In practice, the maximum speed of a GPRS connection is the same as modem connection in an analog wire telephone network (about 30 to 40 kbps, depending on the phone used), and its latency is very high. GPRS is typically prioritized lower than speech in the mobile networks, and thus the quality of connection varies greatly.

Other options There are other options for adding connectivity to a PDA, but today they are not very common. These include:

- **Universal Mobile Telecommunications System (UMTS)** is the most deployed 3G technology, specially on GSM networks, as it uses GSM infrastructures and W-CDMA air interface. It supports up to 384 kbit/s data transfer rates, enabling new mobile services like videoconferencing. During 2006, UMTS networks in many countries have been or currently are in the process of being upgraded with High Speed Downlink Packet Access (HSDPA), sometimes known as 3.5G.

- **High-Speed Downlink Packet Access (HSDPA)** is a 3.5G mobile telephony protocol in the HSPA family, which provides a smooth evolutionary path for UMTS-based networks allowing for higher data transfer speeds. Current

HSDPA deployments now support 1.8 Mbps or 3.6 Mbps in downlink. Further steps to 14.4 Mbps and beyond are planned for the near future. Some mobile operators are already shipping smartphones with this capability.

- **Worldwide Interoperability for Microwave Access (WiMAX)** is the most popular name of the IEEE 802.16 standard, officially known as WirelessMAN. It is a standards-based technology enabling the delivery of last mile wireless broadband access as an alternative to cable and DSL. While it has been deployed in many places (specially rural areas), there are very few (if any) mobile devices that use this technology as of today.

2.1.1.5 Other Hardware

Other important hardware features of PDAs include:

Storage A common characteristic of mobile devices, be it either PDAs or smartphones, is their limited storage capacity. Most modern devices are in the range of the hundred Megabytes of permanent storage (in the form of Flash memory), and a comparable amount of RAM memory. This imposes a heavy limitation on the footprint of the operating system and the applications to be run on the device, which must be very optimized (specially because some room should be left for user data).

To alleviate this situation, many PDAs have slots for **memory cards**, being the most common formats **Secure Digital (SD)**, **Multimedia Card (MMC)** and **Compact Flash (CF)**. With these kinds of cards, the storage capacity for user data and applications can grow to several Gigabytes.

Input Devices In PDAs, the most common input device is the **touchscreen**, which is used in conjunction with a stylus or pointer, in the same way a mouse is used in desktop PCs.

Less common is the **QWERTY keyboard**, a small sized version of the conventional keyboard, that greatly eases the input of textual data. In devices which *don't* include this feature, some kind of **virtual keyboard** (an onscreen version of the keyboard, to be used with the stylus) is provided.

Another option for input devices is the use of external IrDA or Bluetooth devices, for PDAs that support that kind of wireless communication.

Other Common Hardware Other common hardware features of PDAs include **digital cameras**, **GPS receivers**, etc. As these devices are only important for certain applications, and not concerned from the operating system point of view, we will not make any further comments on them.

2.1.2 PDAs and Linux

Today, Linux counts only for a 1-2% of the worldwide PDA shipments, which are dominated by Microsoft's Windows Mobile (with more than 50%) [26]. The cause for this is that traditional PDA manufacturers had their own proprietary operating systems (Palm, RIM), or decided to go with the safe bet that Microsoft represented (Dell, HP and others). Notable exceptions for this trend can be found in the Asian market, where Linux-based PDAs are more common (i.e. Sharp Zaurus PDAs).

However, in the expanding sector of smartphones and "converged devices" (devices that share capabilities of both PDAs and mobile phones), Linux has a much more promising outlook. This area is now dominated by Symbian OS, but Windows Mobile and Linux phones are gaining ground swiftly, and previsions state that by 2010, both Windows and Linux devices will outnumber Symbian ones [42, 17].

2.1.2.1 Manufacturers of Linux-based PDAs

In the modest Linux PDA market, most of the manufacturers that ship Linux-based devices are of Asian origin, and many of the models are nowhere to be seen in the European market. Major players are:

- **Sharp** is probably the best known manufacturer of Linux PDAs, with its **Zaurus** models. Although they did quite well in the Asian market, they are next to impossible to get in Europe and North America.
- Nokia has recently released its **770 Internet Tablet**, with an operating system based on Debian (Maemo), demonstrating that even the company behind Symbian is considering Linux as a valid OS in its most advanced devices.
- There is a plethora of less well-known brands manufacturing PDAs, specially in the Asian market, like **Q-Reader**, **Olympus**, **Mizi**, **G.Mate**, **Q-Reader** or **Empower**.

2.1.2.2 Other Linux initiatives for PDAs

Apart from manufacturers that ship PDAs with a Linux-based operating system, there are a number of initiatives, promoted by manufacturers or communities of users, who want to use Linux in devices that do not originally come with it preinstalled:

- **HP/Compaq** sponsors the community **handhelds.org** [16], whose aim is "to encourage and facilitate the creation of open source software for use on handheld and wearable computers.". Although its aim is general, their most widely known result is the **Familiar** distribution, developed primarily to be installed in the HP iPAQ PDAs.

- **OpenZaurus** is the free and open version of a Linux operating system for the Sharp Zaurus PDAs, developed by a community of developers which wanted other features than the ones provided with the original device [40].
- Although it is not an initiative to put Linux into a handheld device, the **Debian** community (more concretely, the Debian ARM port [10]) has a wealth of software packages that can be used in mobile devices. In fact, many of the existing distributions for PDAs, like Familiar or Maemo, are based on Debian.

The major problem that many of these initiatives share when trying to adapt Linux to a PDA is that many manufacturers don't want to (or can't) disclose the specifications of their hardware devices, delivering a "closed" package of hardware and software. In many cases, these communities have to experiment and "hack" the devices to install Linux in them. Some exceptions to this rule include HP or Sharp.

2.1.2.3 Common hardware support in Linux-based PDAs

As most of these efforts are community-based, and often do not have direct support from the manufacturers, Linux driver support is in many cases weaker than in their proprietary counterparts. Hardware features commonly supported by Linux include:

- Framebuffer or X11 video output
- Touchscreens, including virtual keyboard applications
- WiFi network interfaces
- Bluetooth connectivity
- Memory card reading/writing (CF and/or SD formats)

The different Linux distributions for PDAs, their features and concrete hardware support will be reviewed in more detail in deliverable D2.3.2, which deals with the software requisites of XtreemOS-MD.

2.1.3 Future Trends

If the data on current market share was not very coherent across market studies, the future trends of PDA market can be even less so. But there are some general trends that seem quite clear [42, 17, 28]:

- The shipping of PDAs will stagnate, or raise slightly, thanks to the growth of "converged devices" (Phone+PDA+Internet+Mail), that counteracts the swift fall of "unconnected" PDAs.

- The smartphones will become mainstream, as they take over PDA features and their prices drop, while the market for PDAs will continue to be stable, targeting bussiness users.
- Converged device operating systems will be dominated by Symbian in the short term, but Windows and Linux will erode Symbian's market share, and will eventually overcome it. Which of the two will come out as the winner is still unclear, although it seems that Linux has more possibilities in the Asian market.
- PDA and smartphone operating systems will tend to convergence (that is, there won't be a Windows OS for PDAs and another one for smartphones, as it happened in the past).
- WiFi connectivity is becoming commonplace in new PDA models.
- Until the battle for the wireless broadband is decided, the manufacturers will restrain from adding WiMax to many of their models.
- PDAs will not use conventional hard drives, but bigger flash drives.
- The use of Compact Flash (CF) and MultiMedia Cards (MMC) flash memories in PDAs will decrease, while the use of Secure Digital (SD) cards, and its variants (miniSD, microSD), will increase.

2.1.3.1 Strategy to Handle Market Trends

When considering the endeavour of creating a Linux-based Grid operating system for mobile devices, and taking into account the foreseeable trends, it seems logical to go for a PDA version on a first phase, as they provide more hardware features and more stable software, making a better platform for first experiments and a basic (or "unoptimized") version of XtreemOS-MD. This first version will use hardware and network specifications of modern and high-end devices now in the market, trying to anticipate how PDAs will look like in the near future.

Then, in one or two years, the market for smartphones will be more stable, and the Linux initiatives for this kind of devices, now sparse and heterogeneous, will probably converge (in fact, there have already been some approaches between them [29]), defining one or more standards along the way. They must do so if Linux is to play a significant role in this market. Also, that period will enable us to adapt and optimize XtreemOS-MD, not only to run on smartphones, but also to do it more efficiently and provide support for "killer" Grid services and applications.

As we have already noted, many PDAs are proprietary hardware/software bundles. The only tool in our hands to overcome this problem is to make XtreemOS-MD open source software, thus encouraging manufacturers interested in this kind of functionality to adopt XtreemOS modifications to Linux. Besides, to provide more advantages for the adoption of XtreemOS, the mobile device flavor will closely follow the emergence of Linux mobile device standards and initiatives.

Nevertheless, this "device closeness" issue cannot be ignored altogether, and thus XtreemOS-MD will provide support only for certain "open" devices.

2.2 State of the Art in Mobile Virtual Organizations

In this section, current solutions for dealing with mobility will be reviewed. First, current Internet standards and their support for mobility will be discussed. After that, we will examine mobility issues affecting Grid computing.

2.2.1 Information Society and Mobility

The proliferation of laptops, PDAs, mobile phones and other mobile computing devices in our society has turned mobility into a crucial issue in today's communications. In the context of Computer Science, mobility means "accessing to information, communications and services always and everywhere".

The Internet was designed assuming that computing nodes would have a fixed location within a given subnet. Hence Internet addresses were used for routing purposes as well as for identifying nodes. However, in today's mobile information society, this assumption is no longer valid. Mobile devices do not have a fixed physical location and they can move from a subnet to another. Moreover, these changes may occur while communications are taking place and they should be seamless to the parties involved in the communication.

Another problem concerning mobility is related to the fact that a mobile node may receive coverage from several wireless access points at the same time. This means that a mobile node may be reachable by not one, but several IP addresses. The mobile node should then be able to use these addresses in parallel and switch between them dynamically in the case of failures. This feature is known as multihoming. Although multihoming in IPv6 is not yet standardized, the use of multiple interfaces is foreseen to provide ubiquitous, permanent and fault-tolerant access to the Internet, particularly on mobile nodes which are prone to failure or sudden lack of connectivity [30].

2.2.1.1 Mobile IP

The most promising approach for handling the mobility problem is represented by the Mobile IPv6 protocol, standardized by the Internet Engineering Task Force (IETF) in RFC 3775 [21]. This is an extension to the IPv6 [11] protocol—and also a step further over the former MIPv4 [34] protocol—that allows a mobile node to maintain its connectivity when moving from one access router to another. This process is known as handoff or handover.

To ensure its success, Mobile IP's designers had to meet a number of important goals. The resulting protocol has these key attributes and features:

Interoperability Mobile IP devices can operate with existing IP devices that do not use Mobile IP.

Seamless Device Mobility MDs can change their physical network attachment method and location while continuing to be reachable by their static IP address.

Session Persistence Ongoing communications will seamlessly continue when a MD changes its physical network attachment.

No New Addressing or Routing Requirements The overall scheme for addressing and routing is maintained. This means that internal network routers do not need any modifications.

Layer Transparency The changes introduced by Mobile IP are confined to the network layer. Transport layer and higher layer protocols and applications are able to function as in regular IP.

Limited Hardware Changes Only software in the MD and routers used directly by the MD need changes. Routers between the home and visited networks do not need to know about Mobile IP.

Scalability Mobile IP allows a device to move between any two networks, and supports this for an arbitrary number of devices.

Security Mobile IP includes authentication procedures to prevent an unauthorized device from causing problems.

Both MIPv4 and MIPv6 rely on giving the *Mobile None* (MN) a fixed IP address which receives the name of *Home Address* (HoA). Packets sent to this fixed IP address will be initially forwarded by the *Home Agent* (HA) to the actual MD IP address, which is also referred to as the *Care of Address* (CoA). The node that is communicating with the MN receives the name of *Correspondent Node* (CN).

Because this method can be inefficient in some cases (packets from the MN to the CN have to go through the HA), MIPv6 establishes the route optimization feature (optional in MIPv4) as a fundamental part of the protocol. Route optimization allows messages from the CN to be routed directly to the MN without the HA participating in the communication (see figure 2.1).

2.2.1.2 Future of Mobile IP

Several enhancements have been proposed for Mobile IPv6. The following enhancements have been given "experimental" status by the IETF and mainly deal with reducing the amount of signalling and handoff times for mobile connections.

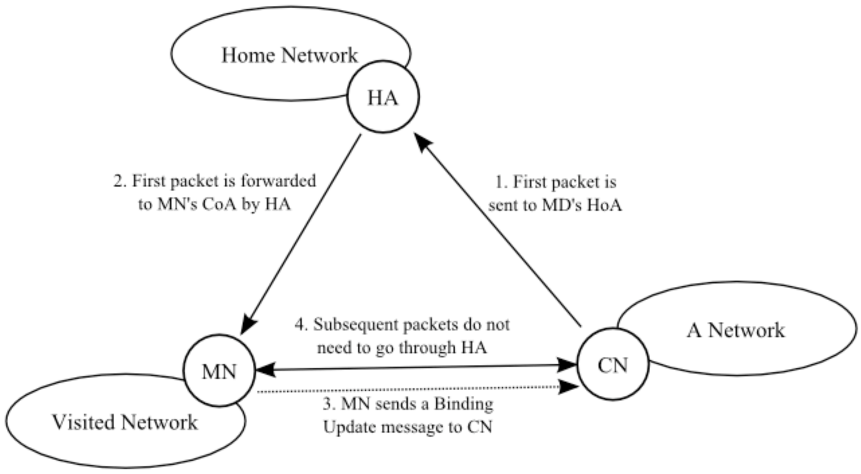

Figure 2.1: Route Optimization in IPv6

Hierarchical Mobile IPv6 Hierarchical Mobile IPv6 (HMIPv6) is standardized in RFC 4140 [38]. HMIPv6 tries to reduce the signalling required in handoffs by using a hierarchical approach. The idea of a hierarchical approach was taken from its IPv4 counterpart "Mobile IP Regional Registration" [14].

Using Mobile IPv6, a MD has to send binding update messages to all its correspondent nodes when it changes its location. This requires a quite large amount of signalling traffic that can be reduced by using a hierarchical approach.

Hierarchical Mobile IPv6 (HMIPv6) introduces a new node, called Mobility Anchor Point (MAP) which plays the role of a local Home Agent for the mobile node. The mobile node will maintain two Care-of Addresses, one from its current subnet (which changes on every handoff) and the other one from its MAP (which usually stays the same). If the mobile node changes its location inside the domain of a same MAP, the MAP care-of address will not change and hence communications can continue tunnelled through the MAP.

Fast Handovers for Mobile IPv6 Fast Handovers for Mobile IPv6 (FMIPv6) is defined in RFC 4068 [24]. This protocol tries to improve handoff latency times by anticipating the handoff in advance.

The FMIPv6 protocol allows a mobile node that is going to move from a subnet **X** to a new subnet **Y** to use the connection to subnet **X** to get information about its access point and associated subnet prefix in the new subnet **Y**. In this way, when the attachment to the new access point takes place the mobile node already knows the new router's network prefix, IP address and MAC address. FMIPv6 defines a signalling protocol between the old and new access points to perform this IP address configuration.

2.2.1.3 Other approaches to mobility

Although Mobile IP is the natural approach to handling mobility in today's Internet, many other approaches have been proposed for dealing with the problem of mobility [19, 23, 35, 41]. In this section, two of the most promising alternatives, the Host Identity Protocol [32] and the Session Initiation Protocol [36], will be discussed.

Host Identity Protocol The Host Identity Protocol (HIP) [32] is still at Internet Draft status, although its architecture is already defined in RFC 4423 [31]. This protocol is actually a new layer between the network and transport layers. In this new layer, the Host Identifier (HI) is used as an endpoint name to identify nodes regardless of their physical location. The goal of HIP is to isolate routing information (the IP address) from the host identity, so that it is possible to establish a connection using a HI rather than an IP address (which is location-dependant).

Session Initiation Protocol The Session Initiation Protocol (SIP) [36] was created as a protocol for creating, modifying and terminating sessions with one or more participants. These sessions can be VoIP calls, video streams, and/or multimedia conferences. SIP runs on top of several transport layer protocols, such as TCP, UDP, or the more recent SCTP [39, 35].

Schulzrinne and Wedlund [37] described how the SIP protocol can be used to provide applications ranging from Internet telephony to presence and instant messaging with mobility features.

The main advantage of using the SIP protocol for implementing mobility is that it can be used on top of a regular IPv4 or IPv6 network without mobility support. On the other hand, being an application-layer protocol, it requires applications to be modified in order to support mobility.

2.2.2 Mobile Virtual Organizations

Until recently, Grid research has focused only on fixed systems. However, mobility is becoming a hot topic also in the field of Grid computing. Mobile Grid computing deals with making Grid services available to mobile nodes at any time and anywhere. A solution to accomplish this goal consists of implementing mobility at the lower levels of the communication protocols, so that the mobile nature of nodes is transparent to the Grid infrastructure.

Because host mobility is handled by Mobile IP as it has been explained in section 2.2.1, little work has been performed concerning mobility and Grid computing apart from those trying to enable current Grid middleware to work with IPv6, which offers a better mobility support than the former IPv4. The projects EUChinaGRID IPv6 [13] and 6Grid [1] are two examples of this work. The Open Grid Forum (OGF) IPv6 working group [33] is working on considering the impact that IPv6 will have in Grid computing. The European IPv6 Task Force [12] has also considered the implications of enabling IPv6 into Grid systems [20].

The only project that goes beyond Mobile IPv6 and introduces the implications of mobility in Virtual Organizations is the EU-funded project Akogrimo [3], which will be described next. Another EU-funded project, Daidalos, will also be studied because of the fact that its advancements in the seamless integration of mobility services could be of interest for mobility in XtreemOS.

2.2.2.1 Akogrimo

The Akogrimo research project [3], funded by the European Commission, is currently dealing with the problem of incorporating mobility-awareness into the Grid. This project aims at a mobile Grid architecture to be validated within the scenarios of e-Health, e-Learning, and disaster handling and crisis management. Akogrimo defines a mobile Grid as follows:

> A mobile Grid consists of resources that are not centrally controlled and supports various kinds of mobility. It communicates using standard, open, general-purpose protocols and interfaces to deliver nontrivial and optimized Quality-of-Service (QoS) depending on the current context of the resource or user.
>
> Furthermore, there is bidirectional cross-layer cooperation between the mobile Grid middleware and the underlying network.

In Akogrimo, virtual organizations can provide services to other virtual organizations. From its generic idea of virtual organization, two derived concepts have been defined by the Akogrimo project[5]:

Base Virtual Organization (BVO) The Base-VO is a static VO that manages all the actions performed within the Grid environment. For instance, it provides the means to register users, services, and other metadata such as Service-Level Agreements (SLAs) and workflow templates.

Operative Virtual Organization (OpVO) The OpVO is more dynamic than the BVO. It is used to instantiate a business process and manage its execution. The creation of an OpVO is initiated by the associated BVO. The lifetime of an OpVO is the same as that of its associated business process.

For instance, when a business process is instantiated and executed by a user, an OpVO is created by the BVO. This OpVO uses the repositories that the BVO provides about users, services, and other metadata such as SLAs and workflow templates in order to execute the requested business process.

Moreover, Akogrimo also introduces the concept of mobile dynamic virtual organization (MDVO), which is a VO grouping together several providers that agree to share their resources for creating more complex, value added services. [6]

Akogrimo also defines two kinds of services [22]:

Infrastructure Support Services These services are always present and they are mainly used to perform control and management actions. In Akogrimo, the Execution Management Service (EMS) is an example of infrastructure support service that queries mobile devices about the services that they provide, their availability, QoS, etc.

Application Specific Services These services are invoked by the infrastructure support services when required for workflow execution. The execution of these services is performed within a separate OpVO created by the BVO Manager. Application specific services can be seen as a set of services that cooperate in order to perform a common task (i.e. they can establish a communication between a doctor an a patient because an anomalous activity has been detected in the patient's heart.

Not only does Akogrimo allow mobile users to use the Akogrimo network, but it also allows the effective use of the MDs as an active part of the network. Nonetheless, "heavy" services requiring powerful computational resources are typically hosted by fixed nodes in Akogrimo.

Four kinds of mobility are supported by Akogrimo:

User Mobility A user must be able to access personalized services regardless of the terminal that he/she is using to access the Grid. In Akogrimo this is accomplished by the user performing his/her registration in the Grid prior to the use of network services. This registration process associates a given user with a terminal. Akogrimo distinguishes between mobile users (those who move while in online mode) and nomadic users (those who change their location while in off-line mode). For the registration phase, Akogrimo uses the EAP [2] and PANA [15] protocols, which allow the use of different authentication mechanisms.

Terminal Mobility User communications must not be disrupted by movements that might involve changes in network topology. Akogrimo makes use of Mobile IPv6 to solve this problem. Without Mobile IPv6, changes from one access point to another would cause the loss of open connections and a new IP address being assigned to the terminal.

Session Mobility In Akogrimo application sessions can be transferred between different devices without interruption. In Akogrimo this is achieved with the SIP protocol (see section 2.2.1.3), which is used by the user and Grid infrastructure to redirect communications without losing track of the user identity.

2.2.2.2 Daidalos

Daidalos [9] is another EU Framework Program 6 Integrated Project, currently in its second phase, Daidalos II. Although not directly related to Grid Computing, this project seeks the seamless integration of heterogeneous network technologies in order to enable ubiquitous and seamless pervasiveness across personal MDs. This project covers several specific points to serve mobile users.

Daidalos is also based on Mobile IPv6. It addresses as broad fields as mobility, Authentication, Authorization, Accounting, Auditing and Charging (A4C), security or Quality of Service (QoS).

This project is strongly based on scenarios. Two main scenarios are defined in its report "D1.1.1: Consolidated Scenario Description" [7]:

Automobile Mobility This scenario shows how Daidalos makes use of mobility to support services in and around a vehicle. It incorporates aspects of access to personal information, presence location and detection, service and content adaptation based on QoS, session mobility and broadcast services.

Mobile University This scenario applies to the organization of daily life in a university. The scenario shows features such as resource discovery and location, or personal broadcasting.

Just like Akogrimo, Daidalos enables context-awareness and service pervasiveness. Results from the first phase of Daidalos include the design, prototyping and validation of the infrastructure and components for efficient service distribution over diverse network technologies (802.11 among them).

The project also developed a network architecture enabling the seamless use of personalised communication services, such as e-mail or digital video, while moving from fixed-line Internet at home or in the office to mobile broadcasting in a car.

These results are the basis for its next phase, Daidalos II, which will introduce the following improvements:

- Support functional integration for end-to-end services across heterogeneous technologies
- Separate the user from a device, thereby offering flexibility as well as privacy and personalisation
- Enable pervasiveness across personal and embedded devices, and allow adaptation to changing contexts, movement and user requests
- Integrate broadcast at both the network and service level
- Permit network operators and service providers to offer and receive services, allowing players to enter and leave the field in a dynamic business environment

The results of both phases of Daidalos are of interest for XtreemOS mobility, as they introduce innovative concepts related to mobility in IP networks (using protocols such as MIPv6), service pervasiveness, and seamless integration of different network technologies.

Chapter 3

Hardware/Network Requirements for VOs in Mobile Devices

In this section, we will list and explain the hardware and network requirements for XtreemOS-F in its flavour for mobile devices. These requirements have been gathered from several sources, including:

- Research on state of the art in mobile devices (summed up in section 2.1)
- Previous research on mobile Grid (i.e. Akogrimo project)
- Previous research on mobility (i.e. Daidalos project)
- Requirements from XtreemOS Grid applications, extracted in WP4.2 (mainly deliverable D4.2.1 [8]) and further refined here.

We have classified these requirements into three categories, according to their importance and degree of complexity. These categories are:

Basic These are the first and most important requirements for XtreemOS-MD, and without them, fulfilling the others wouldn't be feasible. Thus, these are the ones that should be implemented first.

Advanced These are requirements that, due to their increased complexity or lesser importance, should be implemented in the advanced version of XtreemOS-MD. Of course, if time allows, some of them can be included in the release of the basic version.

Optional These are less important requirements, although they are desirable in a mobile and ubiquitous system.

Therefore, the necessary information to define a requirement is:

- Requirement identifier (RMDX.Y.Z).
- Short name.
- Brief description.
- Detailed description.
- Source of the requirement (dependency):
  - Deliverable D4.2.1, indicated as Rn (being n from 1 to 101).
  - Additional mobility information gathered from a survey circulated to the reference aplications, indicated as “Survey”.
  - State of the Art (chapter 2), indicated as “State of the Art”
- Level of importance: Basic/Advanced/Optional.

3.1 Requirements for Virtual Organization

The following requirements have been extracted from a preliminary study on state of the art in mobile devices, and from previous research done in other EU-funded projects and international efforts (IETF).

The main goal of XtreemOS-MD is to adapt XtreemOS to **mobility** scenarios. But before we can set the requirements for mobility, we must define *what we mean by mobility*. Previous research [5] has detected several kinds of mobility, which must be addressed before we can achieve a truly mobile and ubiquitous system:

Terminal mobility The user can change his location (i.e. access point), be it either in offline mode (nomadicity) or online mode (mobility). In this last case, the session should be maintained. This kind of mobility is often achieved at service or application level, but lower layers can make this task easier, so this kind of mobility will also be taken into account in WP2.3.

User mobility The user can access Grid services (maybe personalized to fit his needs) from any location and device. Once again, this is normally done at service/application level but, as this can be aided from lower layers, we will also cover it in WP2.3.

Session mobility The user can transfer an ongoing session from one device to another, maintaining the session. This is more directly related to each application and to what implications the session has for each one of them. As such, it will be addressed (to make such operations easier) in WP3.6.

Another important notion commonly found in mobile scenarios is that of **context**, meaning the metadata referring to the user, which includes not only his profile and preferences, but also information on his location, surroundings, device, etc.

This kind of information is very useful in order to provide adequate services to the end user. Normally, context gathering and processing services are implemented at service or application layer, and are quite domain-specific. However, part of this information can be obtained from lower layers, and we will try to cover them as much as possible in both WP2.3 and WP3.6.

RMD2.3.1: Compatibility

> *XtreemOS-MD must run on the most common hardware in the market of PDAs (basic version) and mobile phones (advanced version).*

It is important that XtreemOS-MD runs on the most common hardware available in the market of mobile devices. This will provide XtreemOS with a sufficiently large base of potential users so as to ensure the success of the operating system.

Depends on: State of the Art
Importance: Basic

RMD2.3.2: Battery Shortage

> *XtreemOS-MD will notice users and services in the mobile devices when it is running out of battery and allow a proper disconnection process.*

Battery shortage is a common situation when dealing with mobile devices. Therefore, it is necessary for XtreemOS-MD to take this problem into consideration and to be able to notice the user and the system itself, in order to let them disconnect and close any running services and applications properly.

Depends on: State of the Art
Importance: Basic

RMD2.3.3: Input Interface Mechanisms

> *XtreemOS-MD must allow users to easily interact with the operating system and applications.*

Users of XtreemOS-MD must feel comfortable using the operating system. They must be able to use special input methods such as touchpad screens. Classic input via keypad also needs to be supported.

Depends on: State of the Art
Importance: Basic

RMD2.3.4: Optional Input Methods

Other input methods can be supported by XtreemOS-MD.

For mobile devices, more advanced input methods such as handwriting recognition or voice commands may be supported in order to ease the use of XtreemOS-MD.

Depends on: State of the Art
Importance: Optional

RMD2.3.5: Context Support

XtreemOS-MD must provide the means of extracting available information about the device's hardware and connectivity, for use in context-aware services.

Although context gathering and processing functionalities are normally implemented at a higher level (service level or even application level), it is important that lower layers (like XtreemOS-F) provide methods for context information gathering, regarding the device's hardware and network capabilities. The availability of this kind of information will depend on the extent to which the specific hardware is supported in Linux (availability and quality of the drivers), as driver development is clearly outside the scope of this project.

Depends on: State of the Art
Importance: Advanced, subject to driver support for Linux

RMD2.3.6: Interoperation

Devices running XtreemOS-MD will be able to communicate to other XtreemOS devices regardless of their current location, provided that the terminal has network connectivity.

The mobile nature of the devices in which XtreemOS-MD will run will have to be taken into account. This may involve enhancements in the network stack of this flavour of XtreemOS in order to support terminal mobility and compensate for network latency, handoff delays, etc.

Depends on: State of the Art
Importance: Basic

RMD2.3.7: Connectivity Detection

The user of a MD must be able to know whether he/she has network connectivity (online/offline).

The user must be aware of whether he/she has connectivity or not, because many of the actions he can perform will be affected by this connectivity. Besides, applications can make use of connectivity status to change their behaviour (i.e. change presence information, etc.).

Applications will also have access to information about current reception level (signal strength) so that they can take actions when signal falls under a critical level.

Depends on: State of the Art
Importance: Basic

RMD2.3.8: VO Management Interruptions

VO-related operations performed from mobile devices will not compromise system integrity.

Any kind of VO management operations executed from a mobile device must not compromise VO system integrity, due to interruptions like those caused by network disconnection or battery shortage.

Depends on: State of the Art
Importance: Basic

RMD2.3.9: Offline Operation

Users of XtreemOS-MD should be able to access a certain subset of information even when there is no network connectivity.

XtreemOS-MD should take into account the fact that MDs may have serious connectivity problems (i.e. bad reception, handoffs, etc.). In order to make up for these limitations, XtreemOS-MD will act on a best-effort basis, storing critical information when connectivity is present and providing this information even in offline mode.

Depends on: State of the Art
Importance: Optional

RMD2.3.10: Service Resume

XtreemOS services should be able to be resumed after a connection interruption.

This requirement does not apply to all services, it depends on service characteristics, and will only take effect for a limited amount of time (for example it will only work for network disconnections of a maximum duration; after that moment, service will not be able to be resumed).

Depends on: State of the Art
Importance: Optional

3.2 Requirements from Applications

Several requisites for mobile devices have been extracted from application requirements. They can be classified into hardware, network and software requirements; both hardware and network requirements will be described in this document, while software requirements will be detailed in D2.3.2.

These requirements have also been gathered from a survey filled in by the partners who provide the mentioned applications. In this survey, partners were asked to think of their applications running on a MD and afterwards answer some critical questions.

RMD2.3.11: Kinds of Applications Supported by XtreemOS

XtreemOS must equally support data-intensive and CPU-intensive applications.

Most of the applications considered are either data-intensive or CPU-intensive. Some of them (SPECWEB, HLA, SIMEON) are both, whereas SRC, TIFON and JOBMA are neither data nor computation-intensive. Regarding data-intensive applications it is essential that XtreemOS can efficiently manage access to central and distributed databases and can also handle file-based applications.

Therefore, MDs must have a minimum CPU performance and storage capacity to become a node of XtreemOS-MD.

Depends on: R1
Importance: Basic

RMD2.3.12: Heterogeneous Hardware

XtreemOS must support heterogeneous hardware.

The XtreemOS system shall run on heterogeneous nodes with different architectures and different memory and storage capacities. Some applications are programmed to be platform-independent and do therefore support heterogeneous architectures. Certain applications like ELFIPOLE or ZEPHYR benefit from homogeneous architectures to facilitate runtime prediction.

Since there is not a unique criterion about hardware needs for applications, various hardware configurations will be accepted.

Depends on: R2
Importance: Basic

RMD2.3.13: XtreemOS Must Support IPv6

XtreemOS must support IPv6 to take advantage of this kind of addressing.

XtreemOS must support IPv6, which implies that it must support MIPV6 to handle terminal mobility issues.

Depends on: R11
Importance: Basic

RMD2.3.14: Limited Time to Perform VO Management Actions

> *VO management actions must be completed within a specified maximum amount of time.*

Various applications require that a VO can be created, changed and destroyed within a certain maximum amount of time. In some cases (HLA, SIMEON, WISS) this response time needs to be a couple of seconds or at most 10 minutes. It is therefore necessary that VO users can in advance define how fast management actions need to be performed with respect to each application (to be agreed with the VO administrator).

This requirement leads us to ask MDs for both a minimum required bandwidth and a maximum allowed latency, enabling VO management operations to be completed in a certain amount of time.

Depends on: R26
Importance: Basic

RMD2.3.15: Confidential Data Communication

> *Confidential data communicated between resources in the same VO must be transported via confidential channels associated with the VO resources.*

There is a need for mechanisms that protect messages and responses in transit between computational nodes over insecure channels. More specifically, confidentiality of data is concerned with the protection of message inputs and the corresponding outputs of responses from invalid observers. However, the security policies and mechanisms are now concerned with the properties of the channels over which messages and responses are transmitted. In order to not transmit confidential by an insecure channel, all the data for which a user or application owner can not adjust security preferences (e.g. IPC, process migration, ...) are secured by a cryptographic scheme and protocol by default. Users and application owners should specify individual security preferences for their communication. 50% applications indicated that confidentiality of transmitted data was highly critical. A typical rule-of-thumb is to aim for prevention before detection, such that it should first be endeavored to restrict illegal principals from reading data in transit.

MDs, therefore, must be able to connect to secure networks whenever it's necessary. Confidentiality mechanisms will also be restricted by MDs' CPU constraints.

Depends on: R79
Importance: Basic

RMD2.3.16: CPU performance for XtreemOS crypto mechanisms

> *Multiple bundles or configuration for XtreemOS crypto have to be considered to support different CPU performance constraints. The minimal set of resources and properties (e.g. CPU performance, memory) can be specified per VO resource.*

In some cases partners have indicated that they expect a solution that consumes less than 0.5% of the CPU, while others have indicated a maximum CPU consumption of 50%.

This will also impose constraints to the minimum resource requirements (CPU, memory...) of MDs, once these crypto mechanisms and bundles are defined.

Depends on: R93
Importance: Advanced

RMD2.3.17: ARM Architecture Support

> *Hardware restrictions: XtreemOS for MD must support ARM architecture for PDAs and mobile phones.*

Three applications (21%) point out hardware restrictions concerning mobile devices. One of them considers PDA's and Mobile phones to be inappropriate for their requirements, while the other two specifically require ARM processors.

This will lead us to ask MDs support ARM architecture.

Depends on: R95
Importance: Basic

RMD2.3.18: Lightweight Security Methods

> *XtreemOS for MD should also support lightweight security methods to improve MDs' performance.*

42% applications allow MDs to use lightweight security methods (e.g. shorter keys to cypher communications) to improve their performance, due to their small processing capacity.

Depends on: R101
Importance: Optional

RMD2.3.19: Maximum Disconnection Time

> *There must be a maximum amount of time for MDs to be disconnected.*

Some applications wouldn't be able to run on a node if it was disconnected from the Grid for more than a certain amount of time (e.g. 5 minutes for EADS applications).

Depends on: Survey
Importance: Basic

RMD2.3.20: Critical Services

> *MDs must not hold critical services.*

MDs have not to be used to hold critical services of the Grid but those that can cope with disconnections, due to MDs' reliability constraints.

Depends on: Survey
Importance: Basic

RMD2.3.21: Several Network Interfaces

> *XtreemOS-MD must support several network interfaces.*

XtreemOS-MD must be able to jump from a network access point to another to try not to lose connection (multihoming). The MD will detect which access points are available and choose the best one; if this one was lost, the MD will connect to the Grid through another network access point.

Depends on: Survey
Importance: Advanced

RMD2.3.22: Java Requirements

> *A Java Runtime Envirenment (JRE) must be available for XtreemOS architectures.*

XtreemOS-MD will take into account the existence of Java Runtime Environments when choosing a hardware achitecture to be supported.

Depends on: Survey
Importance: Basic

Chapter 4

Hardware/Network Specification for Mobile Devices to Support VOs

In this section, the specifications for mobile devices will be extracted from the requirements in chapter 3. The fields that describe each specification are the same as the ones used for the requirements. In contrast to the requirement identifier, the specification identifier will have the format **SMDX.Y.Z**, the capital “S” standing for “specification”.

4.1 Hardware Specification

These are the hardware requirements for MDs extracted from requirements in chapter 3.

SMD2.3.1: Minimum Configuration

> *MDs must have a minimum CPU, memory and storage configuration to host XtreemOS-MD.*

This configuration must be as tight as possible in order to make XtreemOS-MD available to most MDs on the market.

Depends on: RMD2.3.1, RMD2.3.11, RMD2.3.16
Importance: Basic

SMD2.3.2: Hardware Architecture

> *XtreemOS-MD must run on ARM architecture.*

As deduced from 2.1.1.2, ARM is the most widespread standard architecture on the market of MDs. This makes compulsory its support by XtreemOS-MD.

Porting XtreemOS-MD to other architectures will be possible considering its open code nature.

Depends on: RMD2.3.1, RMD2.3.17
Importance: Basic

SMD2.3.3: Minimum Performance

> *MDs must have a minimum performance so as to support cryptographic algorithms.*

Since cryptographic algorithms will be necessary to meet security requirements, a minimum CPU performance will be necessary to support them.

Depends on: RMD2.3.16
Importance: Basic

SMD2.3.4: Screen Resolution

> *MDs must have a screen resolution of 320x240, 640x480, or higher*

These are the most common screen resolutions that we have found during our market study. Smaller ones are becoming unlikely (considering the market trend to large screen resolutions) and could compromise XtreemOS-MD applications and services visualization. There shouldn't be any problem to support bigger screen sizes than these ones.

Depends on: RMD2.3.1
Importance: Basic

SMD2.3.5: Battery Monitoring

> *MD must provide accurate information about its battery status.*

Battery shortage must be a predictable event and MD hardware must notice it to MD operating system (OS). A MD that suddenly runs out of battery will become unavailable without notifying other nodes. For this reason, it is important that the MD be able to report battery level to XtreemOS so that it can take action whenever battery charge goes under a certain level.

Depends on: RMD2.3.2
Importance: Basic

SMD2.3.6: Service Resume

> *MD needs to provide enough memory to store service messages for a specified amount of time when connection to a service is interrupted.*

The spare memory needed depends on supported disconnection time and the nature of the service.

Depends on: RMD2.3.10
Importance: Optional

SMD2.3.7: Input Interfaces

> *Mobile devices must have at least one of the following input interfaces:*
>
> - *Touchpad screen*
> - *Keypad*

Users must be able to communicate with the OS via the MDs' input interfaces. Touchpad screens are the most common input interface in PDAs, whereas only keypads are usually found on mobile phones.

Depends on: RMD2.3.3
Importance: Basic

SMD2.3.8: Microphone Support

> *MDs may incorporate a microphone.*

Optionally, MDs can incorporate a microphone which will be supported by XtreemOS-MD. The presence of a microphone can be useful for implementing voice recognition capabilities.

Depends on: RMD2.3.3
Importance: Optional

SMD2.3.9: Device Hardware Openness

> *There must be enough information available about a given device's internals so that a new OS can be installed on the device.*

In many cases, manufacturers do not release their devices' internal specifications (used chips, IO ports, schematics, etc.). This information is critical when building an OS for a given device. Hence, devices for which this information is not available will not be supported by XtreemOS-MD.

Depends on: None
Importance: Basic

SMD2.3.10: Java Runtime Availability

> *A Java Runtime Environment (JRE) must exist for the MD hardware architecture.*

In order to be able to execute Java applications on XtreemOS-MD, a proper JRE must be available for the mobile device hardware architecture.

Depends on: RMD2.3.22
Importance: Basic

4.2 Network Specification

SMD2.3.11: Support for MIPv6

> *The network interface must support Mobile IPv6.*

If MDs are becoming XtreemOS nodes, MIPv6 is necessary to keep them available under mobility conditions.

Depends on: RMD2.3.13
Importance: Basic

SMD2.3.12: WiFi Support

> *Mobile devices must be provided with a WiFi (IEEE 802.11) network interface supported by the Linux kernel*

As we will focus our efforts on the WiFi technology, initially this will be the only supported network interface (see section 2.1.1.4 on network interfaces). On the other hand, most of today's PDAs are equipped with a WiFi interface, and Linux WiFi support is becoming more and more stable. Consequently this requirement should not impose a strong restriction for mobile devices. To meet confidentiality requirement means that WiFi network interface should at least support WiFi Protected Access (WPA) to assure proper data encryption.

Depends on: RMD2.3.6, RMD2.3.7, RMD2.3.9, RMD2.3.14, RMD2.3.15
Importance: Basic

4.3 Example technologies that fulfil the specification

Some devices that currently fulfil these specifications are:

- HP iPAQ hx4700, rx3700 series, h3100 series (with a WiFi CF expansion)
- Sharp Zaurus SL-6000L, SL-C3000 (with a WiFi CF expansion)

- Dell Axim X50 series
- Nokia 770 Internet Tablet

All these devices have WiFi network connectivity, which is the most commonly used network technology in PDAs, which covers our networking requirements.

Initially, our developments will be carried out on an HP iPAQ hx4700 device. Once XtreemOS-MD gets mature enough on this device, we may move on to other cutting-edge PDAs and/or smartphones (in the advanced version of XtreemOS-MD), such as the new Qtopia Greenphone, the Motorola A760, or the FIC Neo1973.

Chapter 5

Conclusions

In this document, after analyzing the state of the art in mobile devices and Mobile Grid computing, we have presented hardware and network requirements and specifications for virtual organization support in XtreemOS-F for MDs.

It has been assumed that laptops will have enough storage and processing capacity so as to be able to run the standard version of XtreemOS. Therefore, we will focus our efforts on personal digital assistants (PDAs) for the basic version of XtreemOS-MD and smartphones for the advanced version.

To reach accurate conclusions, we approached a study on the mobile device market, summarized in this document, in order to establish the state of the art. This study was very useful in order to define a set of feasible and future-proof requirements and specifications for the mobile devices.

As stated in section 2.1.3, basic version of XtreemOS-MD will support PDAs, while advanced version will work on smartphones too. This has a technological as well as a market reason. In the first place, PDAs are a more stable platform for development, with richer hardware and network features than smartphones. Furthermore, PDA market is more mature, and in the lapse of time between basic and advanced version, smartphone market will also be more stable and Linux initiatives in the area should be ready at that time.

Regarding mobility, Mobile IPv6 will be the path to follow in the future. XtreemOS-MD will make use of Mobile IPv6 in order to implement terminal mobility, allowing a mobile node to maintain its connectivity when moving from one access point to another.

In the field of mobile Grids, currently the most important research effort is represented by the Akogrimo project, which introduces the concept of mobile dynamic virtual organizations (MDVO), and several other concepts that can be useful for our work.

Another relevant EU-funded project, Daidalos, has made much progress on enabling context awareness and service pervasiveness using Mobile IPv6 and hence this workpackage can benefit from this project's results.

Hardware and network requirements imposed on XtreemOS by the reference applications (XtreemOS deliverable D4.2.1) have been drawn. Besides, other requirements derived from the state of the art in mobile devices, mobility and virtual organizations have been included in the document. These requirements show that XtreemOS-MD should be able to run on the most common hardware devices available on the market, allow users to easily interact with the operating system and support VO operation.

All those requirements have been translated into MD specifications in chapter 4, separating them into three kinds of specifications: basic, advanced and optional. In this process we have identified what MDs need to become XtreemOS-MD nodes in its basic version (basic specifications), its advanced version (advanced specifications), as well as some desirable characteristics, that have been qualified in the document as optional specifications.

This specifications will allow us to begin the first experiments with mobile devices. Moreover, alongside the software/operating system requirements to be drawn in next deliverables, and the work from other workpackages like WP2.1 (VO support in Linux) and WP3.5 (Security), it will set the stage for the design of a truly mobile, VO-enabled operating system.

Chapter 6

Future Work

This document is just the first step towards the construction of a complete operating system for mobile devices that supports virtual organizations (VOs) in a truly mobile and ubiquitous way. Further steps that we can anticipate right now include:

T2.3.2 After determining hardware and network requirements and specifications, the same process must be followed at the software level, paying special attention to the operating system (higher-level Grid services will be taken care of in WP3.6). A study on the current Linux initiatives and distributions for mobile devices will be carried out, to ascertain what the best starting point of our XtreemOS-MD efforts is. At the same time, and following the same process of this document, we will extract software and OS requirements from the applications and current research on mobility and virtual organizations. Then, a more detailed software and OS specification will be laid out.

T2.3.3 Once we have all the requirements in place and a complete specification has been done, the time will come to put forward the design and architecture document for XtreemOS-MD, detailing the main elements and building blocks that will make it a mobile operating system with support for virtual organizations.

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