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XtreemOS

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

Requirements and Specifications for Advanced VO Support in Mobile Devices
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Executive Summary

Grid computing and other sibling concepts like metacomputing, virtual organizations (VOs) or the more recent "cloud computing", have been around for more than two decades. However, they have failed to reach wide acceptance, except among certain scientific communities and, even there, complaints are often heard about the difficulties of using and administrating it, specially in large scale projects. The **XtreemOS** project aims to change this situation by delivering a modified Linux operating system with grid capabilities embedded in it, so that operating inside VOs is transparent for users, easy to manage and scalable to thousands of nodes.

Moreover, it has also been an old aspiration of grid computing to extend its reach, not only to PC computers, but also to any machine capable of providing any kind of computing, storage or interface capabilities, from high performance computing (HPC) clusters to mobile phones. XtreemOS also addresses this aspiration, by the inclusion of several flavours of the operating system, for PCs, clusters and mobile devices. **XtreemOS-MD** is the flavour of XtreemOS designed to run in mobile devices like mobile internet devices (MIDs), personal digital assistants (PDAs) or mobile phones, but this software could also be easily made to run over other kinds of embedded devices such as set-top-boxes or satellites.

At the time of this writing, the implementation of the basic version of XtreemOS-MD, providing a Linux operating system for PDAs and MIDs which integrates grid client functionalities, is being finished. The present document sets the stage and the vision for the **advanced version** of XtreemOS-MD, which will extend hardware support to more limited devices (such as smartphones), and it will also include advanced optional functionalities not present in the basic version. This revision of the aims and goals of XtreemOS-MD is motivated, for the most part, by the rapid evolution of the mobile market, whose advancements could easily render XtreemOS-MD obsolete or difficult to disseminate and exploit.

After a study of the state of the art in Linux mobile phones and mobile devices in general, the **revised vision** of XtreemOS-MD could be stated as follows:

Building a mobile grid OS composed of a set of open source modules that are easily integrable with any mobile Linux OS, providing a thin client to grid resources in a scalable fashion, regardless of its hardware architecture, and allowing for the sharing of mobile resources with this grid.

In order to realise this vision, XtreemOS-MD has been divided into two layers: a low-level foundation layer (F-layer) which embeds virtual organization concepts into the operating system mechanisms, and a high-level grid services layer (G-layer), which implements and coordinates the interactions among multiple nodes across the VO, to provide distributed computing and storage in a secure manner. The present document deals mostly with the **foundation layer** of XtreemOS-MD, defining its requisites and deriving more concrete specifications from them.

In order to extract these requisites, the **use cases** for XtreemOS-MD (which were first defined during the design of the basic XtreemOS-MD) have been updated and expanded. These use cases, along with the state of the art and market trends in mobile devices, have allowed the definition of the **requirements** for the advanced F-layer of XtreemOS-MD, such as support for additional hardware (smartphones), leverage of several network interfaces, transparency for non-expert grid users or other additions to the existing grid client functionality.

Afterwards, these requisites have been refined into more concrete **specifications**, transforming *what* has to be done into a more specific description on *how* these operations should behave: customization of user interfaces, easiness of installation and management of VO functionalities, or optional features such as context awareness and execution of grid processes in mobile devices.

This document also points out the directions of the **future work** to be done in this workpackage to design and implement the advanced XtreemOS-MD: the election of a smartphone Linux distribution to base the smartphone version of XtreemOS-MD on, the porting of the existing basic version to that new software stack, or the porting of that same software to PCs, in order to have a thin, lightweight client that is also usable for common PC users.

Finally, directions for **immediate research** are pointed out, to assess the feasibility and design of completely new features that could be added to the advanced XtreemOS-MD, such as context awareness features, the sharing of mobile resources as grid resources, advanced VO support features or the possibility of creating short term, ad-hoc VOs.

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Glossary

AMS	Account Mapping Service
ARM	Advanced RISC Machine
ARMEL	ARM Emulator
API	Application Programming Interface
CN	Correspondent Node
FSUID	File system UID
GNOME	GNU Network Object Model Environment
HA	Home Agent
ICMP	Internet Message Protocol
IKE	IPSec Key Exchange
IPsec	Internet Protocol security
IPv6	Internet Protocol v6
KRS	Key Retention Service
MD	Mobile Device
MN	Mobile Node
MIPv6	Mobile Internet Protocol v6
NSS	Name Service Switch
PAM	Pluggable Authentication Modules
PDA	Personal Digital Assistants
PEM	Privacy Enhanced Mail
PKCS	Public-Key Cryptography Standards

RADVD	Router Advertisement Daemon
SA	Security Association
SAGA	Simple API for Grid Applications
SSH	Secure Shell
SSL	Secure Socket Layer
SVN	Subversion
TCP	Transport Control Protocol
UID	User Identifier
USAGI	UniverSAl playGround for Ipv6
VO	Virtual Organization
VOM	Virtual Organization Manager
WP	Work Package
XtreemOS-MD	XtreemOS for Mobile Devices

Chapter 1

Introduction

This document sets the first milestone of the work in the advanced version of XtreemOS for mobile devices (MDs). Although its main objective is to define the **requirements** for the Foundation layer of this mobile flavour, the goals and the **vision** that steer these requirements also need to be defined. Thus, in this introduction we will present this vision and the methods that will be used to attain it. Due to the changing nature of the mobile device industry, this vision is also prone to change and evolve in the future, and thus it can be addressed in later documents.

Once the requirements for the low-level layer of XtreemOS-MD have been defined, further documents by this workpackage will design the OS-level capabilities necessary to make this vision a reality, and later implement it in the most efficient way.

In parallel with these activities, workpackage 3.6 will work on the requirements, design and implementation of the grid-level services of this mobile flavour, proceeding in close collaboration with WP2.3 to achieve this vision of a grid operating system for mobile devices.

1.1 Advanced XtreemOS-MD: visions and goals

Once the basic vision of a mobile Linux operating system with embedded grid client functionalities has been almost completed[1], it is the right time to revise and readjust the guiding principles that have led us so far, to take into account the current state of the environment in which XtreemOS-MD will be delivered.

The main vision of the basic version of XtreemOS-MD could be stated as follows:

> *Building a mobile grid OS composed of a set of open source modules that are easily integrable with any mobile Linux OS.*

[1]At the time of this writing, finishing touches to the implementation of the basic version of XtreemOS-MD are being implemented, towards its official release in the first half of 2009.

Although this vision is still valid, when developing the advanced version we must take it a step further, specially having in mind the following facts and trends in the mobile device market (please refer to chapter 2 for a summary of this and other interesting information about the state of the art in MDs):

- Mobile devices (both mobile phones and so-called mobile Internet devices – MIDs) are expanding their numbers, and will probably outnumber common PCs in a few years.
- There is an increasing trend about offering remote applications and services, both to PCs and to mobile devices. This is commonly referred to as "offering services in the cloud" or just "cloud computing".
- The number of high-end mobile phones (also known as "smartphones") is growing rapidly, as their prices go down and terminals of this kind, such as Apple's iPhone®, OpenMoko or the first Android/Google phones (e.g. the G1® from HTC), get exposure in the mass media.
- The already-evident market fragmentation in mobile operating systems is being complemented by another fragmentation in the chipset arena, where ARM-based processors are being challenged by the latest, low-consumption x86 processors such as Intel's Atom®.
- Mobile devices' computing resources are increasing, not only in CPU speed and memory, but also with the presence of additional devices such as cameras, GPS, accelerometers, multi-touch devices etc.

All these trends will have to be taken into account when approaching the specification and design of future versions of XtreemOS-MD. First, as it was already planned at the beginning of the project, the hardware supported by XtreemOS-MD should be extended to at least some models of **smartphones**, to take into account their hardware limitations (both computing and interface-wise) and exploit their advantages. Also, the solutions chosen for current and future grid services in XtreemOS-MD must remain **scalable** enough to support scenarios with large numbers of mobile users accessing the resources of the grid. Moreover, and to face the competition posed by smaller and more portable PC-like devices (e.g. MIDs or small, low-consumption netbooks), the client interfaces developed within XtreemOS-MD will be **backported to PC** (x86) architectures; this will also provide XtreemOS with a **thin, transparent client** software that any PC user wishing to try out XtreemOS can install and execute easily without having to migrate the entire system to XtreemOS. Finally, we believe that the **computing resources of MDs** (specially, input/output devices) can be made part of XtreemOS virtual organizations, allowing for more advanced mobile services which can take advantage of the mobility of some of its members.

Then, if we had to reformulate the XtreemOS-MD main goal, we could do it so:

> *Building a mobile grid OS composed of a set of open source modules that are easily integrable with any mobile Linux OS, providing a thin client to grid resources in a scalable fashion, regardless of its hardware architecture, and allowing for the sharing of mobile resources with this grid.*

1.2 Methodology

As it has already been mentioned in past documents [19, 18], a XtreemOS software stack is divided into two big layers: a low-level Foundation (XtreemOS-F) layer providing virtual organization (VO) support in the operating system of the grid nodes, and a higher level Grid services (XtreemOS-G) layer, which coordinates individual resources into services spanning the whole virtual organization. This document deals with the hardware, software and network requirements and specifications of the evolution of the XtreemOS-F layer of the mobile flavour of the operating system.

The methodology that will be used throughout this document is parallel to the one used when defining the requirements of the basic version of XtreemOS-MD-F [22, 21], with a few exceptions:

- The first step of the analysis consists of a study of the **state of the art** in the hardware and operating systems that affect the advanced version, as an extension to the ones done in previous deliverables[22, 21]. Thus, the state of the art will be mainly focused on the area of smartphones, although occasional references to other devices such as MIDs and lightweight PCs can be made where appropriate. This state of the art will be analysed and conclusions relevant for XtreemOS-MD-F will be extracted, pointing to the most adequate strategies for the development.

- Then, the **use cases** for the XtreemOS-MD system will be revised, assessing the extent to which the basic version of XtreemOS-MD covers them, and focusing specially on advanced and optional use cases. From these use cases the potential impact and needs for the F-layer will be assessed.

- Afterwards, the **hardware, network and software requirements** for the basic version will be revised, and new requirements covering the previous analysis will be added to them. Also, the latest requirements stemming from the reference applications workpackage (WP4.2) will be taken into account when detailing this new set of requirements.

- Finally, this set of requirements will be further consolidated into **specifications** for the advanced version of the Foundation layer of XtreemOS-MD. These specifications will set the boundaries within which the design and implementation of the software will be made.

1.3 Document structure

The document follows closely the methodology explained above, and thus it is structured as follows:

Chapter 2 deals with the latest trends in the mobile device area, and provides a state of the art, not only from the hardware device perspective, but also contemplating the networking and software stack aspects of it. In chapter 3 the use cases for XtreemOS-MD (which first appeared on deliverable D3.6.1 [20]) are revised, and useful conclusions for the development of the advanced version are extracted from them.

Next, chapter 4 details the advanced requirements for XtreemOS-MD, which are refined into concrete specifications in chapter 5. Finally, chapter 6 outlines the next steps to be taken in the consecution of the vision of the advanced XtreemOS for mobile devices.

Chapter 2

State of the art

This chapter contains an update and analysis of the state of the art in the area of mobile devices, as an extension to the ones presented in deliverables D2.3.1 [22] and D2.3.2 [21]. It includes a review of the most important news and developments in the area that could impact the development and adoption of the advanced XtreemOS-MD in the next years. Afterwards, we analyse the state of the art in smartphones, the main focus of extension of hardware support in XtreemOS-MD, covering not only the terminals and their capacities, but also their operating systems and network technologies. Finally, we conclude with the impact that this state of the art can have on the development, and measures to be taken in order to optimise our development, release and communication strategies.

2.1 Evolution of the mobile device market

In the period of more than one year that has passed since we last presented the state of the art in mobile devices [21], a good number of news and announcements have occurred, although many of the open questions that we had back then still remain unanswered.

The **smartphones market**, our main focus, continues to grow at a steady rate according to the latest analyses [4, 5], although the worldwide economic recession has made this growth to fall short of the rather optimistic expectations. More concretely, the smartphone share among mobile phones varies from study to study, although it is generally expected that its growth will not be as spectacular as it was up to now, as users end up spending less than expected in substituting their old mobile phones. Regarding the operating systems, again the results of the studies are contradictory, with Linux rising or falling depending on which one is read. It seems certain, however, that Research In Motion (RIM) and Apple seem to be gaining market share. Whether this trend will be affected by the advent of LiMo and Android phones (the first of which is just being unveiled at the time of this writing) or not, it remains to be seen.

The panorama of competing **Linux standardising bodies** and initiatives has begun to clear up, with the fusion of the Linux Phone Standards (LiPS, [8]) group with the LiMo Foundation [7]. This leaves only the Open Handset Alliance (OHA/Android, [13]) and the LiMo Foundation as the main competitors for the standardisation of the Linux smartphone (please refer to D2.3.3 [18] for an in-depth description of these organizations). The first examples of both Linux platforms are beginning to be seen as this report is being written, so it remains to be seen which of them (if any) will dominate the Linux smartphone scene. For example, Motorola recently announced intentions of concentrating more on Android. On the other hand, LiMo released the first version of its specifications [6], to be implemented as middleware in C or C++.

Another interesting development in Linux smartphones was the release of the new version of the only completely **open terminal** (including not only its Linux software stack but also its hardware schematics), the Neo FreeRunner from OpenMoko [14]. In fact, this openness has already prompted the apparition of customizations of the terminal for specialized purposes, such as OpenMokast [3] or NeoPwn [12].

Regarding Linux competitors in the smartphone arena, another potentially crucial event was that of Nokia buying the rest of the **Symbian** shares, and announcing plans to **open source** the operating system (which is, right now, the leader of this market segment) through the Symbian Foundation [17]. With this opening Symbian could match one of the main advantages of Linux, although the exact mechanisms and timeframe for it are still matter of speculation.

Regarding **other mobile devices**, such as those covering the gap between laptops and smartphones, the predictions of the analysts [15] are also of fast growth, although their numbers will remain smaller than those of mobile phones. Of all these “ultra-mobile devices” (UMDs), mobile Internet devices (MIDs) are the ones expected to dominate the market, and although the operating system shares are still unclear, Linux remains one of the main players, with the likes of Moblin and Maemo as noteworthy examples of MID-oriented Linux distributions.

2.2 Hardware

In deliverable D2.3.1 [22], the main hardware features of state-of-the-art PDAs were reviewed. Now we extend that analysis to other device categories, like smartphones and other so-called “ultra portable” devices.

2.2.1 Manufacturers

According to the latest market analyses [4, 5], **Nokia** continues to lead the pack of smartphone manufacturers, with near half (47.5%) of the total market share, more than 100 millions of devices shipped each year. The second biggest manufacturer in this category is Research In Motion (RIM, 17.4%), followed by HTC, Sharp, Fujitsu and others. It is interesting to note the relatively poor performance of Motorola, traditionally an important contender in this area; the split of its mobile device business and the adoption of one of the rising mobile Linux standards could prove key points in its eventual recovery.

Regarding other portable devices, such as mobile Internet devices, the market numbers are still much smaller than the smartphone ones (around 10 million devices sold this year), although some analysts [15] predict that this number will multiply by 20 in 5 years' time. Intel and Nokia seem to be the main drivers of this market, one with its Atom-based devices and the other with its range of Internet Tablets. The evolution of this market will have to be closely followed.

2.2.2 Hardware Architectures

In a similar vein as happened with PDAs, currently **ARM** and its many variants are the **most used** hardware architectures in smartphones, and also in other portable devices such as Nokia's tablets, in some cases including more than one of these ARM cores.

However, the semiconductor industry has seen an increasing **trend** in lowering the consumption of PC CPUs, oriented towards more portable and energy-efficient notebooks and ultra-mobile PCs (UMPCs), which has led to the recent unvealing of smaller devices such as MIDs using Intel's Atom®or AMD Geode®processors. These processors are x86-compatible and thus are expected to run the same kind of binaries as a normal PC.

2.2.3 Input/Output devices

Mobile phones have seen the number and variety of their input and output devices grow with each new generation of devices:

- **Textual input methods** have evolved from the classic numeric keypad to more advanced options such as complete (albeit small-size) alphanumeric keyboards, or touch-sensitive interfaces for entering more complex texts, or even multi-touch interfaces. The main concepts to consider here are the **heterogeneity** of text input interfaces across different terminals, and the fact that, despite enhancements in their usability, introducing text into any smartphone today is still a burdensome **chore**.

- The smartphones have seen how their **screens** have grown in size and quality, until they practically take up all the space of the terminal, in a similar fashion as it did on PDAs. This feature has evolved in order to allow for better visualization of photographic and video data, but the obvious size limitations of the devices still require that most of the user interfaces need to be customized, and also calls for transcoding of multimedia content for an optimal visualization in smartphones.

- **Cameras**, both photographic and video, have become not only commonplace, but indispensable, with many smartphone models sporting even two of them, one for taking pictures/videos and another one to be used in videoconferences.
- **GPS receivers** are also becoming increasingly common in smartphones, either included in the device itself, or attached to it through, for example, Bluetooth.
- Even more exotic I/O devices are available in advanced smartphones, such as 3-axis **accelerometers**, which can provide additional contextual information to users and applications, such as the position of the phone to
- Other input and output devices can also be made available to these devices through their **Bluetooth** interface, such as the aforementioned GPS, headphones and microphones for audio communication, larger keyboards, card readers, methods of biometric identification etc. The possibilities are virtually unlimited.

2.3 Network Technologies

The situation of networking interfaces in **smartphones** has not changed substantially since the last document where it was reviewed [22]. The only significant differences are:

- **WiFi** interfaces are still not universally available in smartphones, although they are becoming increasingly commonplace.
- **GPRS** data interfaces are available in virtually all smartphone terminals, although its price and bandwidth still pose a severe limitation for complex data-oriented tasks.
- **3G and HSPA** interfaces are becoming more and more common, and will substitute GPRS totally in the short term. This kind of technologies can provide the necessary bandwidth and coverage to satisfy moderate bandwidth demands, such as online video visualization or TV on the phone.

In other kinds of devices such as **MIDs**, **WiFi** continues to be the main connectivity technology by far. Some models are being presented using WiMax technology, although it is still too early to know if that technology will be deployed in a larger scale. Thus, it remains a minority option, available only in certain rural and otherwise inaccessible environments.

2.4 Operating Systems

The outcome of battle for dominance in the area of operating systems in smartphones can have a major impact in the diffussion and acceptance of the mobile flavour of XtreemOS. However, this outcome is far from being clear; recent analyses such as [4] show a decrease in the market share of **Linux** smartphones (down to 7.3%), probably caused by the decrease in Motorola's business (one of the main Linux proponents in mobile phones), and Nokia's announcement of open sourcing **Symbian OS** (57.1%), which can make the latter look like a more agreeable option and has served to slow the decrease in market share that Symbian was experimenting in the last months. Microsoft **Windows Mobile** has also managed to keep its market share (12.0%), while Research In Motion (**RIM**) has almost doubled its market share from last year (17.4%), with the advent of the newest Blackberry models.

It remains to be seen if the appearance, at the end of 2008 and beginnings of 2009, of the first wave of Android- and LiMo-powered smartphones will turn this tide for Linux in the area. If not, and also depending on the evolution of the process of open sourcing Symbian (not expected until June 2010), probably that will mean that Symbian will remain the largest competitor in the smartphone OS market, at least in the short- to mid-term.

However, the studies [15, 16] show a more promising future for Linux in the **ultra mobile devices** category (which encompasses MIDs and other middle-tier devices), with predicted market shares of up to 42%. In these studies, Moblin [10] and Maemo [9] are cited as the most likely dominators, although LiMo-based devices are also mentioned.

2.4.1 Linux in Smartphones

Focusing our attention in the different Linux options available for smartphones, **two major options** have come to monopolise most of the public attention, virtually polarising most of the major industry players around them (even if many of them have joined both sides of the competition, another symptom of an unforeseeable outcome):

LiMo Foundation [7] has managed to attract most of the partners of other mobile Linux initiatives, such as the recently-merged LiPS. Among its 48 industry members we can find handset manufacturers such as Motorola or Samsung, telecom operators (Orange, NTT DoCoMo), software developers (MontaVista, Movial), semiconductor manufacturers such as AMD etc.

Although by some as a "press release factory", LiMo has managed to release the first version of its API specifications [6] in the summer of 2008. The LiMo Platform defines a plug-in architecture for its middleware, dividing the functionalities of its software stack into modules that the applications can access using C or C++. Although mobile application developers have this API freely available, the modification of the platform itself continues to be in the hands of the manufacturers, and modifications of the LiMo platform seem to be the prerogative of the big industry players.

First smartphones under the LiMo label have begun appearing in 2008, by diverse manufacturers, although their takeoff seems to be fairly slow.

Open Handset Alliance (OHA – Android) [13, 1] , with the notorious sponsoring of Google, is the other big Linux player, at least in media attention. This initiative is endorsed by more than 30 companies, including telecom operators, semiconductor manufacturers, semiconductor companies and software companies.

The approach of OHA is to develop a Linux-based mobile software stack, and provide application developers with an API and software development kit (SDK) so that applications written in Java can be run over it (Android includes a custom Java VM named Dalvik). Special attention is given to the integration with web and other Internet services.

While this document was being written, the OHA has announced the availability of the whole Android software stack as open source for download [2], probably as a response to Nokia's announcement of open sourcing Symbian at some point in the near future. This announcement closely followed the release of the first version of the Android SDK for application developers.

The first Android phone (the G1) has also been recently released to the public.

In the meantime, the new version of the **OpenMoko** smartphone and software stack [14] has been released. This terminal is not so much directed to the mass market, for everyday use, as it is directed towards embedded and mobile developers wishing to experiment with advanced features (like GPS or accelerometers) in a completely opened Linux smartphone. This openness has already prompted three different software stacks to sprout even inside the OpenMoko project (one using GTK+, the other using Qt, and a third – experimental – one, trying to unify both and be compatible with any graphical toolkit).

2.5 Conclusions: Impact on XtreemOS-MD

From all of the above, a number of conclusions can be extracted about how this state of the art and the evolution of the mobile device market can affect XtreemOS-MD, either in its development strategy (for the Foundation layer, at least) or in its later presentation to the public. The main points to be made are:

- In retrospect, the choice of **Maemo** as a second platform for the basic version of XtreemOS-MD was a good one, given its future expectations for market growth and popularity in the range of mobile Internet devices. Thus, Maemo looks like the main way to proceed with the implementation of more advanced features for XtreemOS-MD, since the platform (both hardware and software) has proven its stability and plans for its near future have already been laid out by Nokia.

- The outlook of the smartphone market continues being unclear, and the current state of the worldwide economy hints at an slower resolution for this "battle of the mobile OSes", if any. Probably the best strategy to follow here is trying to avoid depending too much on any of the now existing options (Android or LiMo)

- The open sourcing of Symbian could pose an interesting option for developing XtreemOS-MD software. However, the timeframe and scope of the XtreemOS project (ending in 2010, just when Symbian is announced to be open sourced) does not allow for this kind of development to take place.

- Network connectivity is not going to be unified in the near future, with 3G and WiFi being the most common of them. XtreemOS-MD should not tie itself too much to any of them, and finding a way for optimising the use of both of them could be an interesting path for research.

- Even in a slower-evolving mobile market, there are a number of interesting developments that XtreemOS-MD should follow closely in the following months, such as the usage of OpenMoko as a starting point for extending its support for smartphone platforms. Also, other recent technologies such as Movial's Browser D-Bus Bridge [11] can provide interesting approaches for integrating grids and other services with mobile devices in an easy and stack-independent way.

Chapter 3

Advanced XtreemOS-MD Use Cases

In order to better focus the features and functionalities that the advanced version of XtreemOS-MD should have, we will review here the mobile use cases that were first presented in deliverable D3.6.1 [20], and see the kind of support that the Foundation layer should give to make them possible.

As we did in the previous document, a priority has been assigned to each of them, attending mainly to **dependency** criteria (i.e. if a use case is required before another one can be implemented, it is given a higher priority), but also on the grounds of the **expected functionality** on a current mobile grid system and its adequateness to the XtreemOS **design principles** of transparency, ease of use and scalability. Thus, “Advanced” use cases should be fulfilled by the advanced version of XtreemOS-MD, while “Optional” use cases are interesting research paths that can be followed, but are not considered crucial for the success of the project. Also following the same conventions, the use cases have been divided into “grid-aware” and “grid-transparent” use cases, attending to the degree of awareness of an underlying grid infrastructure that is possessed by the users.

Unless otherwise noted, the use cases from D3.6.1 labelled as “Basic” have been eliminated, since they are supposed to be already covered in the basic version of the software. The content of the rest of the use cases has been revised, and additional use cases, marked with an asterisk (*), have been proposed inside the XtreemOS Consortium and they have also been added to the list of use cases, and classified accordingly.

3.1 Grid-Aware Use Cases

3.1.1 VO administration

Description

A VO administrator logs into the Grid from his MD and, acting as that VO role, performs an administrative operation (add/delete users, create an VO subgroup, set resource policies, etc.). Since this kind of operations are currently being performed through the VOLifeCycle web application, a mobile user should be able to access it from a MD (e.g. by modifying the appearance of this frontend or developing a new one).

Grid services required

- Access to a XtreemOS VOLifeCycle application
- Access to a XtreemOS Credential Distribution Agency (CDA)

Importance

Advanced.

3.1.2 Resource management

Description

The user could define what resources to share with the Grid as well as monitor its usage (e.g. current status, who is using them, how are people using them, who is allowed to use them, statistics, etc.). Since part of the resource management is currently done through the VOLifeCycle web application, a mobile user should be able to access it from a MD (e.g. by modifying the appearance of this frontend or developing a new one).

Grid services required

- Client interface to contact a XOSd (either directly or through VOLifeCycle).
- Access to a XtreemOS XOSd running in the user's VO.
- Access to a XtreemOS VOLifeCycle application

Importance

Advanced.

3.1.3 Resource searching

Description

The user should be able to get a list of resources available to him. This search could be performed according to certain parameters given by the user (e.g. more than 50% CPU free). Since part of the resource management is currently done through the VOLifeCycle web application, a mobile user should be able to access it from a MD (e.g. by modifying the appearance of this frontend or developing a new one).

Grid services required

- Client interface to contact a XOSd in a remote site.
- Access to a XtreemOS XOSd running in the user's VO.
- Access to a XtreemOS VOLifeCycle application

Importance

Advanced.

3.1.4 Data management

Description

The user specifies where data will be stored, the pattern of access, privacy level, places where data can be stored, required level of consistency and coherence.

Grid services required

- Client interface to specify properties of grid files.
- Access to XtreemFS servers.

Importance

Advanced.

3.1.5 Usage of mobile devices as grid resources*

Description

Applications to be run in a mobile device can be started asynchronously, originating from the XtreemOS fixed grid. Applications would not normally be resource intensive, but rather make use of the device's specific I/O hardware (e.g. camera, GPS) or the fact that these mobile devices act as "personal devices" (e.g. to make an important decision that only a specific user can take).

This execution of external applications in the user's mobile device must be handled with all the necessary security precautions in mind and thus, specific VO policies should be in place to prevent inadequate use of this feature by unauthorised users.

Grid services required

- A working (fixed) XtreemOS installation: AEM, CDA, RCA, VOPS etc.
- A mobile version of a XOSd for execution of applications, or equivalent/compatible services.

Importance

Optional.

3.1.6 Usage of context information for automatic service configuration/optimization*

Description

Context information (such as geolocation, user preferences, user action patterns or device capabilities) is used to automatically configure and optimise the XtreemOS service parameters, whenever the user logs in to the VO from a new location. This autoconfiguration should take place not only in the client side (e.g. configuring the parameters for mounting a volume using the XtreemFS client), but also in the grid side (e.g. moving replicas around to enhance performance and reliability).

For this context information to be available, two elements should be in place: a way for mobile devices to gather the context information available (using GPS, network auditing tools etc), and a context management service that gathers all the context information available and dictates the most adequate actions to be performed according to the context.

Grid services required

- Context gathering services/applications in the mobile device.
- Context management services in XtreemOS (grid-side).

Importance

Optional.

3.2 Grid-Transparent Use Cases

3.2.1 Usage from smartphones*

Description

All the basic functions from use cases described in D3.6.1 [20] should also be available from a smartphone terminal: methods for logging into the VO, single sign-on features, client access to XtreemFS and AEM etc. Modifications to the graphical user interfaces (if any) should be made in order to fit the limitations of these devices.

Grid services required

- Single sign-on mechanisms on the MD.
- Mechanisms for obtaining certificates from the CDA.
- Client access to XtreemFS on the MD.
- Client access to AEM on the MD.

Importance

Advanced.

3.2.2 People as resources

Description

Once a user is logged into the Grid, he can receive requests to participate in Grid applications as a resource (e.g. to make a decision in a complex workflow, to take a photograph of a concrete location, etc.), mainly depending on the application's and the user context.

At any time, if a Grid application needs it, the AEM can pose a request to the user in order to participate in the application by performing a certain task in the way that is needed.

Grid services required

- Context management service (location, user knowledge information, device capabilities).
- Context collection and provision on the MD.
- Ability for executing applications on the MD originating from the grid (see 3.1.5).

Importance

Advanced.

3.2.3 Ad-hoc virtual organizations*

Description

A number of XtreemOS-MD users (and/or other XtreemOS users using e.g. laptops) can come together to a certain place, and easily form short-lived virtual organizations in an ad-hoc fashion, in order to attain specific objectives (sharing of data, computing power, I/O devices or even connectivity). These ad-hoc virtual organizations should possess all the security guarantees of other virtual organizations, even if some of these aspects can be socially-mediated instead of technologically-mediated (e.g. identification through face-to-face interaction).

Grid services required

- Ad-hoc networking capabilities on the MDs.
- Either ultra-lightweight XtreemOS services running on mobile devices, or
- Presence of one or more "powerful nodes" (e.g. laptops) in the ad-hoc network, which can act as core servers for the VO (XtreemFS, AEM, CDA...).

Importance

Optional.

3.2.4 Multiplayer mobile games

Description

In multiplayer games with very high demands on computing power (which the mobile device cannot provide) and/or with large numbers of users, can be offered by using massive amounts of PC or cluster nodes to power games to be visualized from mobile devices.

Moreover, since users have to authenticate themselves with the "game VO" before entering, XtreemOS security (and specially accounting) services can be used to monitor and bill the player according to the usage.

Grid services required

- Access to CDA and Accounting service
- Access to AEM in client mode.
- Visualization services

Importance

Optional.

3.2.5 Usage of desktop applications from mobile devices*

Description

XtreemOS-MD could be used as the underlying infrastructure for the execution of (standard PC) desktop applications from mobile devices. Examples could include word processors, image/video processing tools, etc. These applications would be divided in two or more parts, with a light GUI running on the mobile device and the rest of the application logic being run and managed in remote grid nodes by XtreemOS.

Grid services required

- Client access to the XtreemOS AEM system.
- Desktop applications divided into GUI and backend logic.
- Communication middleware adequate for interactive applications.

Importance

Optional.

3.2.6 My networked mobile*

Description

Users could have all the information they normally have stored in their mobile phone (contacts, bookmarks, media files etc) replicated automatically in the grid, preventing their loss in case of accident or theft. This information could also be made available through a web interface, allowing its modification from a more agreeable interface.

In a more advanced version of this use case, this web interface could also allow using other phone functions such as SMS, MMS, audio/video communication etc.

Grid services required

- Client access to XtreemFS from the MD.
- Audio/video streaming services from the MD.

Importance

Optional.

3.3 Conclusions: Impact on XtreemOS-MD

All these revised use cases will shape the feature set and internal design of the XtreemOS-MD flavour. Although more detail will be given in next chapters about the requirements and specifications that stem from them, we can already anticipate a number of areas of impact in the development of the advanced Foundation layer:

- The first step in the realization of the use cases detailed above should be the **porting to smartphone** platforms, since it is one of the most important features of the new version, and it presents little or no dependencies with other workpackages and XtreemOS systems. This should include not only user interface modifications to adapt to the new form factor, but also the evaluation of their performance in a more limited computing environment. Thus, it is advisable to start with these experiments as soon as possible.
  - This would, in fact, condition the choice of **operating system** (i.e. the mobile Linux distribution) to serve as a base for XtreemOS-MD to the ones open and available in the present. As seen from chapter 2, most likely options here would be OpenMoko and, maybe, Android.
- In order to implement most of the other use cases labelled as "advanced", strong **dependencies** are found with several **other XtreemOS subsystems** (e.g. AEM and XtreemFS), regarding the ability to configure and manage them. Close monitoring and collaboration with the relevant workpackages is in order for this work to evolve as smoothly as possible.
- Most "advanced" use cases will not require major modifications to the **VO support** already existing in the basic version of XtreemOS-MD. However, the optional use cases pose a number of interesting pathways for future research:
  - The **usage of MD resources** by the grid, present in several use cases, would require a level of node-level VO support that is not present in the basic version. This, for example, could include modifications in the kernel such as those needed in the PC flavour. Due to the difficulties of this kind of modification in mobile devices, the investigation of alternatives could also be useful.
  - Although **context-awareness** is normally seen as a service- or application-level issue, XtreemOS-MD Foundation layer could provide some easy and standardised way of providing the context data that it has available (e.g. resource usage, geolocation, etc) to higher layers.
  - The formation of **ad-hoc virtual organizations** in order to share resources can also put additional demands on the Foundation layer, specially if the resources to be shared include atypical ones like network connectivity. The investigation of these mechanisms is another interesting path to explore.

Chapter 4

Advanced Requirements of Linux-XOS for Mobile Devices

In this section we will list and explain the hardware, network and software requirements for the advanced version of XtreemOS-F in its flavour for mobile devices. These requirements have been gathered from deliverables D2.3.1 [22] and D2.3.2 [21], and they have been revised in the light of the state of the art and use cases presented in this document. Also, new requirements have been added where appropriate, and have been marked with an asterisk (*).

These requirements have been grouped into two categories, according to their importance and degree of complexity: advanced requirements and optional requirements. Basic requirements, unless otherwise noted, have been achieved in the basic version, and have been eliminated for brevity's sake.

As usual, the requirements are defined as follows:

- Requirement identifier (e.g. RMDX.Y.Z).
- Short name.
- Brief description.
- Detailed description.
- Source of the requirement (dependency):
  - Deliverable D4.2.1/3/5, indicated as Rn (being n from 1 to 101).
  - Additional mobility information gathered from a survey circulated to the reference applications, indicated as "Survey".
  - State of the Art (chapter 2), indicated as "State of the Art" or Use Cases (chapter 3), indicated as "Use Cases"
- Level of importance: Advanced/Optional.

4.1 Hardware Requisites

RMD2.3.4: Optional Input Methods

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.

Comes from: State of the Art
Importance: Optional

RMD2.3.5: Context Support

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.

Comes from: State of the Art
Importance: Optional, subject to driver support for Linux

RMD2.3.9: Offline Operation

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.

Comes from: State of the Art
Importance: Optional

RMD2.3.10: Service Resume

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).

Comes from: State of the Art
Importance: Optional

RMD2.3.16: CPU performance for XtreemOS crypto mechanisms

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. Due to the interactive nature of most MD operation, the delay in interactive operations involving cryptography should be carefully measured[1], and alternatives should be devised (e.g. from progress indicators, proxying methods to more powerful machines etc).

Comes from: R93
Importance: Advanced

RMD2.3.18: Lightweight Security Methods

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.

Comes from: R101
Importance: Optional

RMD2.3.23: Smartphone support*

All the functionalities present in the basic version of XtreemOS-MD should be ported to at least one smartphone platform. If possible, multiple Linux smartphones should be supported.

Comes from: State of the Art
Importance: Advanced

RMD2.3.24: MID/UMPC support*

All the functionalities present in the basic version of XtreemOS-MD could be ported to one or more ultra mobile platform, such las mobile Internet devices (MIDs), netbooks, ultra-mobile PCs (UMPCs), etc.

Comes from: State of the Art
Importance: Optional

[1]For example, usability tests generally show that delays of up to a second are acceptable, and that the attention of users is maintained for up to ten seconds

RMD2.3.25: Additional I/O devices*

XtreemOS-MD can provide some means for grid services and applications to access some of the more exotic devices available in mobile devices. These can include cameras, GPS receivers, accelerometers or any other device that can be attached to the device (e.g. through a Bluetooth interface).

Comes from: State of the Art, Use Cases
Importance: Optional

4.2 Network requirements

RMD2.3.21: Several Network Interfaces

XtreemOS-MD must be able to jump from a network access point to another to try not to lose connection. 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.

Comes from: Survey
Importance: Advanced

RMD2.3.26: Unified/Automatic Network Interfaces*

In a similar way as described in RMD2.3.21, XtreemOS-MD could provide a unified virtual network interface, but independent of the actual wireless technology that is being used underneath. This interface would choose between the actual interfaces according to cost, expected bandwidth and/or user preference.

This system could also allow the usage of multiple interfaces simultaneously, to improve network performance and reliability.

Comes from: State of the Art
Importance: Optional

4.3 Software requirements

R2.3.7: Software Licensing Mechanisms

XtreemOS-MD must support the same software licensing mechanisms as any other XtreemOS node (i.e. for the distribution of license files, or connecting to license servers). This requirement would only make sense if grid applications could be run on MDs, and thus it is labelled optional.

Comes from: R9
Importance: Optional

R2.3.8: Context Support

XtreemOS-MD must be able to extract information about the hardware and connectivity in the device (free memory, processor type, available storage, connectivity, etc.), in order to be used by context-aware applications.

Comes from: RMD2.3.5
Importance: Optional

R2.3.9: Grid Caching Mechanisms

XtreemOS-MD users should be able to perform certain grid operations even if temporarily disconnected. Those operations would be stored locally and performed when connectivity (and proper authentication) resumes.

Users should be made aware that these operations are done locally (and tentatively, as there is the possibility of them not being possible once the user is reconnected).

Comes from: RMD2.3.9, RMD2.3.10
Importance: Optional

R2.3.10: Easy Installation and Customisation of Mobile Grid Services

Due to the limited resources of MDs, it would be desirable to offer the users a way of installing only the grid services that they expect to use in the future. This can be implemented, for example, through packages, with a "core" package with the basic support for VO operation, and other packages with additional functionalities (i.e. XtreemFS access, AEM access, etc).

Comes from: State of the Art
Importance: Optional

R2.3.11: VO Management from MDs

Users connected to the Grid from MDs will be able to perform the complete set of actions concerning VOs, such as creation, operation, configuration, dissolution, policy definition, etc.

Comes from: R79, GSR4, GSR5, GSR10-GSR15
Importance: Advanced

R2.3.12: Integrity in VO management operations

VO management operations are critical, and when performed from mobile devices, their unreliability (i.e. sudden loss of connectivity) could lead to inconsistencies on VO-related stored metadata, compromising system integrity. For this reason, the necessary mechanisms will be implemented so as to ensure the atomicity of

VO management operations, be it either implementations on the MD or in the VO management services.

Comes from: R20, R27, R99
Importance: Advanced

R2.3.14: Checkpointing and restart will not be compromised by MD churn

It is necessary that checkpoints and restarts performed from MDs are completed successfully, even if the MD loses its connectivity while the checkpoint is being taken. The necessary mechanisms will be implemented so as to ensure the atomicity of checkpointing operations, be it either implementations on the MD or in the checkpointing services themselves.

Comes from: R28–R35
Importance: Advanced

R2.3.19: Interoperability with other Linux-based Operating Systems

In order to promote the adoption of XtreemOS-MD, it is important that the operating system can easily interoperate with other Linux-based operating systems for mobile devices. The reutilisation or easy adaptation of software from other Linux devices is an important factor for XtreemOS-MD's adoption.

Comes from: State of the Art
Importance: Optional

R2.3.20: API Standards as Basis for XtreemOS API

XtreemOS-MD must offer support for the most popular Grid APIs (i.e. SAGA). These APIs could be adapted in order to fit MD's particular features.

Although the implementation of this requirement will be done in WP3.6, any implication for XtreemOS-F must be taken into consideration in this WP, for providing adequate support at the OS level.

Comes from: R44
Importance: Optional

R2.3.21: Interoperability with Middlewares

A main issue in XtreemOS fast adoption might be its interoperability with preexistent Grid middlewares (i.e. Globus Toolkit). That interoperability is seen as an optional requirement as it is not a key feature for XtreemOS but a way to leverage XtreemOS spread.

Comes from: State of the Art, R47, D3.3.1
Importance: Optional

R2.3.22: Session Mobility Interfaces

Most of the session mobility support will be developed in WP3.6. Nevertheless, any implication for XtreemOS-F will be taken into consideration in this WP, once technical details are specified in the corresponding task.

Comes from: State of the Art
Importance: Optional

R2.3.25: Directory Service for Node Monitoring. Publishing

In case the MD can be used as a grid resource, XtreemOS-MD should be able to connect to the directory service to publish node information, including also job and node failures. This implies that this kind of information must be available from the Foundation layer of XtreemOS-MD.

Comes from: D3.2.1
Importance: Optional

R2.3.34: Resource Planning on MDs

It should be possible to perform the reservation of resources (such as cameras, sensors,...) for specific intervals, as well as specifying specific characteristics of the required resources on mobile devices.

Comes from: R61
Importance: Optional

R2.3.35: Distribution

Some means of locating (either geographically, through GPS, or according to logical/network criteria) the mobile terminals should be provided. This could be used for limiting the geographical distribution of jobs launched from MDs (for example, to nodes geographically near the MD).

Comes from: R67
Importance: Advanced

R2.3.38: XtreemOS Custom Access to XtreemFS

XtreemOS-MD must allow users to access XtreemFS grid filesystem using the XtreemFS native interface, so that XtreemFS-aware applications and users can access the data in the grid with the maximum control and efficiency.

Although the implementation of this access is a task for WP3.6, this can have some implications for the F-layer (e.g. support for FUSE and/or certain other dependencies).

Comes from: R68–R76, D3.4.1
Importance: Advanced

R2.3.39: Meaningful Filesystem Information

Users and user applications should be able to see XtreemFS as any other filesystem. Thus, meaningful information about grid users and VOs should be given to them when necessary (i.e. fstat displaying VO IDs and global UIDs, instead of local ones).

Comes from: R68–R76, D3.4.1
Importance: Optional

R2.3.40: OSS Implementation in MDs

XtreemOS should offer OSS mechanisms for memory sharing between grid applications, as any other XtreemOS node.

This kind of implementation would only be useful in the case that grid applications can be executed in MDs, and thus is labelled optional. Again, the implementation would be done in WP3.6, but can have implications in lower layers.

Comes from: R68–R76, D3.4.1
Importance: Optional

R2.3.41: Filesystem Servers in MDs

XtreemOS-MD could implement one or more of the XtreemFS entities (OSD, MRC, RMS), or lighter versions of them, in order to act as a filesystem server.

The implementation of XtreemFS entities in MDs would be carried out in WP3.6. However, some implications in the F-layer are foreseen in that case.

Comes from: R68–R76, D3.4.1
Importance: Optional

R2.3.54: Authentication of Software or Components

As well as for users, XtreemOS-MD must implement an authentication mechanism for software or components in order to ensure the identity and reputation of the software provider. This requirement only makes sense in the case of grid applications being executed on MDs.

Comes from: R91
Importance: Optional

R2.3.55: Support for Crypto Accelerators

XtreemOS-MD will support crypto accelerators to perform encryption tasks more rapidly, due to their limited computation capacity.

Comes from: R94
Importance: Optional

R2.3.56: Reputation

XtreemOS-MD must implement a reputation system to control reputation of users, resources, software, etc. to be taken into account in access control decisions. This means e.g. a user that has previously performed (or tried to perform) some illegal operations within other VOs (and therefore has a bad reputation) will not be allowed to access critical data in our VO.

Comes from: R91
Importance: Optional

R2.3.62: Session Mobility

When a user changes his/her location, it should be able to maintain his/her session. This issue is solved at the application layer, so this requirement will monitor if any special functionality is needed to be implemented at XtreemOS-F level.

Comes from: State of the Art
Importance: Optional

R2.3.63: Modes of Operation

Mobile devices' conditions can vary over time. Depending on these conditions, it can be necessary to temporarily disable some services (i.e. to save battery live).

Comes from: State of the Art
Importance: Optional

R2.3.64: Distribution on MDs*

Some means of locating (either geographically, through GPS, or according to logical/network criteria) the mobile terminals should be provided. This could be used for limiting the geographical distribution of jobs to be executed in MDs (for example, to nodes geographically near the originator of the job).

Comes from: R67
Importance: Advanced

R2.3.65: Mobile Device Development Tools*

XtreemOS-MD must include (probably not as part of the distribution, but as one or more separate software packages) a set of tools to make easier the development of applications for XtreemOS-MD. These can include cross-compiling toolchains, IDEs, etc.

Strictly speaking, this is not a requirement to be met by the operating system, but providing such tools would be very interesting for XtreemOS-MD to gain wider adoption, given the special difficulties of developing for mobile devices.

Comes from: State of the Art
Importance: Optional

R2.3.66: Transparency*

The usage of XtreemOS-MD should be possible for users that do not have specialised knowledge about the system or grids in general. User configuration should be kept to a minimum, and textual user interactions such as asking for passwords should also be minimised, providing adequate graphical counterparts where possible.

Comes from: State of the Art, Use Cases
Importance: Advanced

R2.3.67: Integrability in other Linux distributions*

The modules of XtreemOS-MD should be easily integrable with any other modern mobile Linux distribution, either for smartphones or for other form factors. Thus, dependencies on concrete software stacks should be avoided where possible, and low-level (e.g. kernel) modifications should be avoided when possible.

Comes from: State of the Art, Use Cases
Importance: Optional

R2.3.68: Ad-hoc networking support*

In order to form ad-hoc, temporal virtual organizations, support for capabilities to establish mobile ad-hoc networks (MANets) is necessary in XtreemOS-MD Foundation layer.

If possible, this functionality should be integrated with the different network interfaces, as per RMD2.3.26

Comes from: State of the Art, Use Cases
Importance: Optional

R2.3.69: Advanced isolation mechanisms

The concept of strong isolation between phone-related features and other (e.g. data, multimedia) features present in modern terminals is an important concern for mobile operators when deciding which terminals to adopt. This is due to the fact of those phone-related features are one of their main sources of revenue.

XtreemOS-MD could enhance its acceptance by operators providing stronger isolation between phone- and grid-related features. Of course, this would in itself be a limitation for the system, but would also ensure that those features cannot be misused by malignant grid-originating attackers.

Comes from: R18, State of the Art
Importance: Optional

Chapter 5

Advanced Specifications of Linux-XOS for Mobile Devices

In this section we will transform the requisites from chapter 4 into more concrete specifications, taking the conceptual leap from *what* should be accomplished by the Foundation layer of XtreemOS-MD, to *how* would those operations look like, to an end user or to other XtreemOS components interacting with it.

In order to do this, we have abandoned the specification format that appeared in D2.3.1 [22] and D2.3.2 [21], in favour of the format displayed in D3.6.1 [20], which concentrates less on refining each requirement, and concentrates more on showing **how the system should behave**.

As usual, these specifications have been divided into "Advanced" and "Optional", inheriting these priorities from the requirements where they originated. For easier reference, each of them is labeled with a code in the form AS2.3.X.

5.1 General OS Specifications

AS2.3.1: Smartphone support

The base operating system(s) selected for XtreemOS-MD must support running on smartphone hardware.Examples of operating systems that comply with this include:

- OpenMoko [14]
- Android [1]

Interfaces N/A

Comes from: RMD2.3.23
Importance: Advanced

AS2.3.2: Modifiable base distribution

The base operating system selected must allow for the modification of all the parts of its software stack (with the exception of device drivers and similar low-level software). Examples of operating systems that comply with this include:

- OpenMoko [14]
- Android [1]

Interfaces N/A

Comes from: RMD2.3.23
Importance: Advanced

AS2.3.3: Bluetooth support

XtreemOS-MD should support the addition of additional I/O devices to the mobile device through the most widely available technology, which right now is Bluetooth.

Interfaces N/A

Comes from: RMD2.3.4, RMD2.3.25
Importance: Advanced

AS2.3.4: Offline operation – Resynchronization

Since mobile devices often have varying levels of connectivity, including intermittent network access, an "offline mode" for grid operations would be very useful. This system would cache the outgoing requests until their reception is received, even for long periods of time. On network reconnection, this feature would send all the pending operations.

For this feature to be really effective, similar mechanisms must be in place in the other side of the communication (e.g. the fixed node which is communicating with the MD).

Interfaces Although this operation should operate in the background, without active user participation, the user should be notified when the device enters (or is operating in) this mode. Also, a graphical tool should be made available for users to activate/deactivate this feature, and configure the concrete way it works (e.g. the amount of operations that should be cached, which services should do this caching etc).

Comes from: RMD2.3.9, RMD2.3.10
Importance: Optional

AS2.3.5: Operations customized for smartphone interfaces

All operations with the XtreemOS-MD system should be adapted to the peculiarities of an smartphone interface.

Interfaces This specification mostly deals with the user interface. Typical customizations would include:

- Small screen adaptation
- Minimize textual inputs
- Usage of multiple choice (e.g. drop-down) menus where possible
- Alternate input methods (T9, voice commands...)

Comes from: RMD2.3.23
Importance: Optional

AS2.3.6: Make XtreemOS-MD available for x86 architecture

In order to make XtreemOS-MD available for other kinds of mobile devices (e.g. MIDs, UMPCs), all the software developed should be ported to PC (x86) architecture, thus effectively providing a sort of thin, easy to use interface for PCs, which would ideally not require the installation of a whole new operating system.

Interfaces The user interface would normally remain similar to that of the ARM version. However, depending on the target form factor and software stack, different GUIs could be devised.

Comes from: RMD2.3.24
Importance: Advanced

AS2.3.7: Ease of installation of XtreemOS-MD

If the mobile device and the base Linux distribution allows it, XtreemOS-MD modules should be installable by the user in an easy and intuitive way (i.e. in the case that the user did not have an XtreemOS-ready device). In fact, the choice of base Linux distribution(s) for the advanced version should have this requirement in mind.

Interfaces The user interface for installing software should be graphical, either through a web interface (such as the one in Maemo) or through a graphic interface (similar to the package managers in many Linux distributions).

Comes from: R2.3.10
Importance: Optional

AS2.3.8: Ease of configuration of XtreemOS-MD

Once the XtreemOS-MD software is installed, the process of its initial configuration should be as easy as possible, even avoiding all interaction with the user. Data about the "points of entry" to the grid could be stored in the software packages or in the certificates themselves, to allow for non-expert users to leverage XtreemOS functionality without necessarily knowing it.

Interfaces The user interface should be as minimal as possible, avoiding unnecessary prompts for parameters to the user. Ideally, no explicit configuration by users should take place.

Comes from: R2.3.10
Importance: Optional

AS2.3.9: Ease of customization of XtreemOS-MD

Once the XtreemOS-MD software is running, the number and nature of the services being run or accessed from the device should be easily customizable (e.g. deactivating AEM support while maintaining XtreemFS support, etc).

Interfaces The user interface should be as simple as possible, and should be adapted to the device form factor. Naturally, more advanced interfaces could be available for expert users who want to fine-tune their systems.

Comes from: R2.3.10
Importance: Optional

AS2.3.10: Modes of operation

XtreemOS-MD could support several basic modes of operation, depending on a few basic device context parameters, such as the amount of battery left (or the availability of AC power), or the nature and quality of the network connection (e.g. charging – static position, USB cable networking, etc). Certain XtreemOS-MD services could be stopped or started using those parameters (e.g. share the phone's resources only when the device is on AC power), in order to optimise battery consumption or network usage.

Interfaces The user should be notified (e.g. via a small graphical applet) about which mode of operation is in use at every moment. Also, a simple way of switching modes should be available. Optionally, a more advanced interface for selecting how each mode would exactly behave can be developed.

Comes from: R2.3.63
Importance: Optional

AS2.3.11: Alternatives to password input

Alternatives to the typical textual password/passphrase input (e.g. for decrypting a private key) could be devised, to improve usability. Possible examples of these alternatives include:

- The 4-digit personal identification number (PIN) in the phone's SIM card could be used for encrypting information
- The PIN could be used for unlocking a password manager where the real passphrase is stored
- The credential could be stored in the SIM card itself, protected by the PIN as the rest of its information
- A Bluetooth fingerprint reader could be used to authenticate the user or decrypt any encrypted data in a similar fashion

A modular way of implementing these processes should be devised, in order to be able to substitute one method for the other easily.

Interfaces Graphical user interface should be simple or non-existing, depending on the nature of the alternative.

Comes from: RMD2.3.23
Importance: Optional

5.2 Networking Specifications

AS2.3.12: Unified network layer

In order to optimise network usage by devices with multiple network interfaces (like most smartphones, which have WiFi and 3G interfaces), a unified networking layer could be devised, to offer a single contact point for applications. Underneath, this layer would auto-configure itself to enable or disable the different network interfaces, or even use them together for enhanced performance or reliability.

This auto-configuration would take place according to a set of predefined or user-set policies which take into account battery usage, cost, expected bandwidth usage, etc.

Interfaces An intuitive way of configuring this network layer should be available for users, to configure the policies that will be used to decide when and which networks to use. This interface should allow for changing among different modes manually, apart from making "intelligent" decisions about the configuration according to the aforementioned policies.

The user should be notified about what real interfaces are being used at the moment (even if applications only "see" one interface), in case he wants to modify the configuration that has been taken by default

Comes from: RMD2.3.21, RMD2.3.26
Importance: Optional

5.3 Grid/VO Support Specifications

AS2.3.13: Advanced isolation through virtualization

It is not uncommon in mobile phone architectures to make use of virtualization techniques, not for dividing the already scarce resources of the MD, but for ensuring the isolation between the computer-like and the phone-like sides of these devices.

XtreemOS-MD could explore this path and implement a way of ensuring strong isolation between phone-related and grid-related functionalities, to avoid undesired interactions between both sides.

Interfaces N/A (this feature should be transparent for the user).

Comes from: R2.3.69
Importance: Optional

AS2.3.14: Mobile devices as grid resources

Mobile devices running XtreemOS-MD could be made available to the grid as resources. This would include not only their CPU for process execution or their storage for filesystem usage (which would be quite useless anyway), but specially the interactivity with users through graphical interfaces, and other specialised I/O devices such as cameras or GPS.

In order for this to function, XtreemOS-MD would have to provide information about all these resources and their status to the corresponding directory services in the XtreemOS grid.

Interfaces The interface between a mobile resource and the rest of the XtreemOS infrastructure (AEM or XtreemFS) should be made through the same interfaces and protocols that are already defined for the other flavours of XtreemOS. However, modifications and additions to them could be possible to cater for the special circumstances of mobile devices.

No special user interface would be needed for this functionality, apart from a way for users to configure the degree to which the mobile device resources are shared (e.g. "only the camera, not the storage or other processes").

Comes from: R2.3.25, R2.3.34, R2.3.41
Importance: Optional

AS2.3.15: Ad-hoc VO formation and resource sharing

XtreemOS-MD could allow the formation of temporal virtual organizations in an ad-hoc fashion, for example by gathering in a single space and establishing a basic ad-hoc network for resource and data sharing. These ad-hoc VOs would ensure that this sharing is performed securely.

These ad-hoc VOs should not necessarily be formed by mobile nodes only, but more powerful nodes should also be able to enter them and provide their powerful resources for usage by the mobile nodes.

Network connectivity to the exterior of the ad-hoc network could also be considered a resource to be shared (and, probably, one of the most valuable at that).

Interfaces An intuitive user interface should be designed in order to make the whole process of setting up a VO easy and straightforward, probably by educated guesses about many of the parameters of the system, and by the usage of predetermined VO templates.

Comes from: R2.3.68
Importance: Optional

AS2.3.16: Transparency in grid operations

XtreemOS-MD should allow for common file and process execution tasks to be performed through the grid in a transparent way, as if they were being done locally. Examples would include:

- Access to an automatically-mounted XtreemFS home volume using the same file manager, as if it were any other directory
- Execution of non-ARM binaries in the grid (by automatically detecting the binary format and allocating the process to a suitable grid node), redirecting its output to the mobile device and thus creating the illusion of local execution.

Interfaces The user interfaces should be exactly the same ones as they already exist for local MD operation.

Comes from: R2.3.66
Importance: Optional

5.4 Context-awareness Specifications

AS2.3.17: Context gathering and providing

XtreemOS-MD, as an operating system, should be able to gather a number of elements of context data from the device, like battery and network status, CPU and memory load, GPS location, movements and position, and provide them to other elements like mobile applications and other XtreemOS components that could make use of the information.

Interfaces This context data should be offered, both to applications and to other XtreemOS components, using a standardised interface and format, to maximise its usefulness.

This feature should not need a user interface, unless users want (and are permitted) to configure which context parameters are available to others, to preserve user privacy.

Comes from: RMD2.3.5, R2.3.8
Importance: Optional

Chapter 6

Future work

Once we have defined the requirements for the advanced Foundation layer of XtreemOS-MD, a number of steps must be followed in order to design the system and later implement it:

- The very first step will be to choose at least one mobile (smartphone) Linux **distribution**, to serve as a base for XtreemOS-MD for smartphones. This distribution(s) will be added to the ones supported in the basic version.

  Currently, OpenMoko and Android seem the most plausible options due to their openness, that would allow early experimentation with them. Both will have to be tested against the requirements in order to prove their suitability.

- Afterwards, the different research paths will have to be explored, in order to decide their feasibility and interest for the XtreemOS project, which will dictate their inclusion in the XtreemOS-MD feature set (or not). Main directions to follow are:

  – The implementation of **advanced VO support** features, including different schemes for isolation of grid and phone functionalities.

  – The inclusion of **context-awareness** features in XtreemOS.

  – The **execution of grid processes in mobile devices**, specially regarding the usage of human interaction and specialized I/O devices.

  – The formation of lightweight, **ad-hoc virtual organizations**, formed mainly by mobile devices and, possibly, one or more PC nodes.

All these steps will be reflected in the next deliverable, D2.3.6 "Design of an advanced Linux version for mobile devices". Afterwards, the implementation phase would begin, with the following roadmap:

- The feature set that will be defined in D2.3.6 will have to be **implemented**, not only on the smartphone platform but also on the PDA/tablet (basic) platform.

- Afterwards, all the functionality already present in the basic Foundation layer of XtreemOS-MD will have to be **ported to this new software stack**(s). This step is conceptually straightforward, but experience dictates that probably some dependency problems will be found.
- In parallel with that porting, another one will take place to port all the functionality of **XtreemOS-MD to an x86 platform**, in order for the software to be available also for other form factors like newer MIDs, netbooks or even laptops not wanting to install the whole XtreemOS distribution.
- And finally, **development tools** and environments should be put in place, not only for making XtreemOS-MD developers' lifes easier, but they will also be crucial if external (embedded) developers are to be lured into the XtreemOS community.

All these developments will be part of the last deliverable of this workpackage, D2.3.7 " Linux-XOS for MD/MP".

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