Software Infrastructures for ad-hoc networks oriented to difficult environments

WP1T1

DISI - Universita' di Genova
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Abstract

This report presents a number of issues in hardware and software for mobile devices in a MANET, including some considerations on sensor networks, which show several similarities to MANET. Links to various websites and more details are added inside a specific Links section.

Operating Scenarios:

This section describes two typical operating environments, one for a civil protection group in a disaster area, the second for attendees at a large sport event. Requirements for special hardware and software are highlighted in the various possible situations.

Hardware

This section contains a selection of available devices at project starting date, including comparative tables with data about PDAs, tablets and Access points (with or without routing functions). Laptops may be considered as other kinds of mobile devices for the project; information on commercially available laptops is not included.

Peripherals

Useful peripherals listed in this section include: camera, wifi card, GSM-GPRS card, memory expansions for PDA, GPS card (listed as “accessories” by vendors). Remarks on Linux compatibility of these peripherals are included.

Software

Java, JXTA, GCC and Python are already available in a PDA-Linux compatible version. More tools are available for WinCe, but they are outside the scope of the project.

Processors

Further considerations on PDA underlying hardware architecture, which is based on the StrongArm or on the Xscale processors

Protocols

The possibility of using IEEE 802.11 protocols is supporetd in various ways, this section describes in more details the implications of choosing IEEE 802.11b or 802.11g.

Operating Systems

A brief summary of considerations for selecting Linux for the project.

Simulation tools

This section describes in some details one of the most widely used network simulators, ns2, and the MobiEmu environment.OPNET?

Sensor networks

This section contains information about hardware and software for wireless sensor networks, which show several similarities to MANET in initialization and reconfiguration aspects. Hardware vendors and the most interesting software related projects are listed with links to respective websites.

Links

A section which collects the most interesting websites where material to derive the report can be found. These websites were accessible and useful at the time the report was initially written (spring 2003 with minor extensions/updates afterwards).

More information can be found in the LINKS that follow each section.

Analysis of two operating scenarios

The first scenario describes a situation where a MANET may be used during civil protection operations. The next scenario describes a possible use of a MANET as a complementary communication structure in case a very large number of users are collected by a sport event.

The first scenario: Earthquake at Casal Ballerino

On June 2, 200X an earthquake reaching the 7º degree Richter hits the area around Casal Ballerino. The Civil Protection reaches the area about 2 hours later, and settles the "base camp" 5 km away from the epicentre. The base camp has many wireless devices:

- Satellite or cellular devices for connecting to the wired network (if available)
- Radio connections with the operative teams (located from 5 to 10 km away)
- Radio connections (802.11, ...) for short distance communication

Each rescue team consists on an autonomous group of 5 people; each team has:

- A 4x4 vehicle with transmitters to connect to the base camp and to team members
- A PDA for each team member providing wireless connection to the vehicle and possibly to other team members
- GPS and other devices for each team member, including videocameras to document the situation

The mission of these rescue teams includes

- First aid and transport to a safe place for the locals
- Estimate damages to infrastructures
- Block access to dangerous areas
- Start works for securing the area

For example, areas close to the lakes and rivers are potentially dangerous for the risk of floods. It is urgent to identify the dangerous areas and to send people away from them**.** Due to the fall of electric wires, some small fires have started, in certain buildings of the village as well as in the woods: it is a priority to estinguish them, so teams must coordinate their work with the firemen, to direct their vehicles to the fires.

At the base camp, all coordination activity is taking place:

- By GPS connections the position of all teams and all team members is known
- Orders to the various teams are prepared and sent to the devices of each member (Certain orders may require a distributed commit)

- Communication to the Headquarters in Prefettura and to the press originates from here

Assume now that one of the rescue teams, Team 5, is entering the center of Casal Ballerino (the epicentre of the earthquake) for a first check of the disaster area and to coordinate other rescue teams. Each team member has a detailed map of the area on his PDA, and connecting to the territorial DB he/she may fetch more information on the area. The positioning system allows each member to locate precisely his own position as well as the position of other members.

Each member has to report about the status of the buildings, if necessary with images. The information collected so far are automatically shared among team members and with the base camp. While searching for injured people**:**

- Information about injured people shall be immediately forwarded to Teams 6, 7 and 8, consisting on medical staff, who will be responsible for caregiving
- For extreme urgencies the team can make audio-video calls to show the actual situation and do some first-aid intervention under medical remote supervision

Three team members (Andrea, Laura, Mario) have the specific task to check the status of water and gas pipes. They upload the map of these pipes and start the survey of the respective area.

Andrea Verdi has gone too far from the 4x4 vehicle of Team 5, so he has lost connection with the base camp. He goes on with his survey, and the collected data is stored in his PDA; when he meets Laura Bianchi the information that were collected separately are shared among both, and he sees that all the area east to where he is has already been surveyed by Laura. He also realizes that two other team members have already inspected the south area: this inspection was done while he was out of reach (and Laura was in reach). So Andrea decides to go west, and Laura goes north, back to the vehicle of the team.

As soon as Laura approaches the vehicle, all data collected by her and by Andrea (until he met Laura) are uploaded to the base camp and shared with other team members.

Mario’s PDA runs out of power while he is disconnected from the others (except for Andrea, who was near him). Mario goes back to the 4x4 vehicle and takes another PDA; when he fetches all data available: hesees that he has lost the data he surveyed after his last disconnection. But the data is just temporarily unavailable since it was backupped by Andrea: when Andrea connects again, his data contains the last updates, including Mario’s: nothing is lost!

In this scenario, there are two important requirements, security and priority:

- The system must show certain confidentiality degrees (the press should not be aware of everything!)
- The system must be protected from “external” attacks and device malfunctions, which may corrupt the information

- Certain messages have higher priority than others (commands, alerts, etc.)

Less crucial, but important features, could be:

- Use the cellular network
- Use sensor networks

- Exploit helicopters, when available, to:

    - Cover mid-distance connections

    - Synchronize over the time different MANETs

- Exploit other wireless connections (e.g. military)

- Streaming video

The second scenario: Torino 2006 Winter Olympics.

Most of the information collected hereafter has been derived from the website http://www.torino2006.org/. This event is attracting a large number of people, and we may assume that many of them shall be equipped with a mobile device. There shall certainly be a number of WiFi hot spots around the area, but they shall be hardly dimensioned to cover the actual number of people attending the Olympics. The opportunity for P2P communication, with or without networking support, is to be considered important for the entertainment of attendees as well as for those working in the organization.

Here is some data about the event:

- 17 days of competitions
- 15 disciplines

- 7 locations (3 Olympic Villages)

- 2500 athletes and approx. twice as many official delegates

- 1,500,000 tickets issued

Tickets are sold also through a website. It would not be unrealistic to assume that “registered” people in the website shall be allowed to downolad a special purpose software to enable them to exploit wireless facilities while at the Olympics.

Sports are distributed across the Turin area and over time: for example:

- Hockey: located at Torino Esposizioni (downtown), from February 11 to 26
- Bobsleigh: located at Cesana, 90 km from Torino, from feb.18 to 25
- Alpine Ski: located at Sestriere,from feb. 12 to 25
- Freestyle: located at Sauze d'Oulx, 6 days between Feb 12 and 24
- Ski Jumping: located at Pragelato, 6 days between Feb.12 and 24

and the ticketing system allows to buy multiple tickets for one or two consecutive days: people shall move from one location to another, mostly with public transportation. Since each event attracts thousands of fans from anywhere in the world, there shall be a large number of people "on the move" with a mobile device. The actual numbers of tickets sold are:

- Bobsleigh: 7450 people,
- Hockey: 6450 seats,
- Freestyle: 9020 people,
- Alpine skiing: around 9300 people

Consider now what could be the day of one sport fan, Alice, at Torino Olympics on 14 feb 2006. In the morning she is in Sestriere to watch the alpine skiing: she gets to a position where she can watch a very exciting jump, so she takes digital pictures to many competitors with her Java mobile phone. Alice would like to share them with other people so *she has to "post" an announcement.* Bob has digital pictures taken from another side, he reads Alice's post and wants to exchange the images, so *they have to exchange files (directory content and select individual files) in read-only way*. Charlie has only a PDA, he cannot take pictures, and would like to pick up some images from both; Dave is far from Alice's seat, he has a laptop, and he can fetch Charlie's pictures. *File sharing among the four of them is then possible, by routing the communication and the files*.

After the competition is over, Alice is hungry, she asks for a good restaurant in the area. She joins another group of peers, with potentially hundreds of people, for chat and messaging. Later on, she goes back to Torino, because she has an evening ticket for hockey. She takes a bus, and since the trip lasts for more than one hour, she would like to listen to some country music in digital form. Another group of peers can be formed on the bus while moving to share a file stream.

At the same time, the technical staff of the Austrian national team is exchanging information about slope condition: *they want to encrypt the communication, to be hidden from other teams and from reporters*. The organization team is collecting data on traffic in the valley and is discussing weather forecasts: a snowfall is likely, shall we block the private traffic or could it be only a very light snowfall? *This information too is encrypted.*

Alice reaches Torino Palasport to see the hockey match: she is a fan of the Canadian team, tonight playing vs Russia. *Groups of peers in Torino Palasport may be supported by access points; with hundreds of potential connections will it work? Shall we assume a "cloud" of peers extending network connectivity outside AP visibility?*

Networking situations in the above scenarios

Situation A:

In this simple situation, we have only one MANET without any link to the external world. In this situation a working group of people may share common data, for example a data base of territorial information during the emergency situation, or a related set of snapshot at a given sport event. The data may be partially replicated over various MANET nodes. Other possible environments where this situation occurs are those where each group member needs only group communications (no data exchanges to-from outside the group). In this situation communication could be effective only within a limited radius, because of power limitations on mobile radios and because of possible obstacles.

A routing protocol specialized to handle these situations may overcome possible disconnection problems.

Hardware requirements: each unit has a mobile device with WiFi connection, possibly also GPS or webcam.

Situation B:

This situation expands the previous one: the MANET is not connected to the outside world, but there could be some Access Point (Base Station) working as bridges in order to improve the connection among units. These Base Stations can be located in relevant places, and may have omnidirectional antennas to cover a wide area, or directional antennas to reach difficult areas with stronger signals.

As a consequence, in this situation we can imagine our network as divided into "zones" with a tree-like organization: the root is a router, its descendants are Base Station in bridge mode or just mobile units, and all links can be considered static ones (bridge-bridge links always active by means of high gain directional antennas, while bridge-mobile device links can be kept by omnidirectional antennas).

This organization could guarantee total coverage of interesting areas, without requiring wired connections or outside connections. It is important to remember that Base Stations may have high energy requirements, so they should be equipped with long lasting batteries and solar panels. The network spanning tree must also be very low, in order to reduce the traffic among bridges.

Hardware: each mobile unit has a WiFi connection, possibly with GPS or webcam. We need also Access Points to be used in repeater mode, WiFi routers, long-lasting battery and solar panels. Special care must be taken in the choice of antennas and possibly parabolic ones.

Situation C:

The connection to the outside world of the MANET is achieved by possible non-WiFi technologies. These include: connection to a satellite network (geostationary satellites at low orbiters LEO), cellular networks (GSM, GPRS, UMTS) or fixed connections (LAN or Internet). For example, one of the Base stations can be on a van, and may support such external connections as well.

To achieve an end-to-end communication, suitable middleware would select each time the most suitable medium, considering available links and speed-power tradeoffs.

Hardware: each mobile unit has a WiFi connection, possibly with GPS or webcam. We need also Access Points to be used in repeater mode, WiFi routers, long-lasting battery and solar panels. In addition, cellular or satellite communication systems should be installed at least in one Base Station.

Situation D:

As a further expansion of the previous situations, at a certain point some fixed units may be included in the network, such as for example a computer/laptop/tablet connected to a wired link or to a proper power supply network. For example a van containing power generator and servers may arrive later on in the disaster area. We may then consider such a node a special one of the already established MANET, in one of the previous situations.

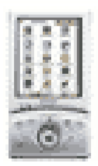
Hardware: as the above ones, plus the non-mobile unit which, from the point of view of the communication, does not cause further communication problems.

Hardware analysis

This section shows what hardware was commercially available at project start, it has not been significantly updated afterwards since improved versions of any such equiupment are always available after some time. Thus it represents a list of minimal devices available for the project. There is a link section where several useful links to hardware vendors have been collected.

PDA:

Here is a list of the best PDAs availale at project start.

Model	**Features**	**Price**
	HP Ipaq h1910 Processor PXA250 200Mhz XScale 48Mb SDRAM, 16Mb NAND Flash	300 euros (and more)
	HP Ipaq h3900 Processor PXA250 400Mhz XScale 64Mb RAM, 32 o 48Mb ROM	500 euros (and more)
	HP Ipaq h5450 Processor Intel 400Mhz XScale 64Mb SDRAM, 48Mb Flash WLAN card (802.11b) Bluetooth card Fingerprint reader	800 euros (and more)
	Sharp Zaurus SL-5500 Processor Intel 206Mhz StrongARM 64Mb SDRAM, 16Mb Flash WLAN card (802.11b)	380 euros (and more)

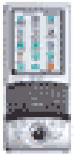
	Sharp Zaurus SL-5600 Processor Intel 400Mhz XScale 32Mb SDRAM, 64Mb Protected Flash Scheda WLAN (802.11b)	N.A.

Table 1: commercially available PDAs

NOTE: Sharp Zaurus have not been commercialized in Italy since 2003. New models available only for US and Japanese markets.

The table above shows that new models are based on XScale processors.

From the software point of view, Sharp supplies the devices with a native Linux O.S., called Embedix (Linux based OS).

On HP devices, the native system is a Windows one (Pocket PC) but a Linux distribution can be installed later on. We have tested them with Familiar.

Since Xscale processors are relatively recent, the first OS releases may not be specifically designed for achieving maximum performance. The most promising model appears to be Sharp SL-5600, the first one to overcome performance problems. If availability in Italy would be guaranteed, Sharp Zaurus SL-5500 would seem the best choice for the project; unfortunately this was not possible at project start.

Laptops:

There are quite many types of laptops that can be used in the project, so the following is just a checklist for possible use of a laptop within a MANET. They should be equipped with at least a wireless pcmcia card 802.11b, and Linux O.S. (no matter what distribution).

Preference should be given to Wireless cards based on Orinoco or Prism chipset for the availability of drivers to handle them. These Linux drivers are seldom given by vendors, but can be downloaded from developers websites (see link). Inserire link driver centrino

Tablets:

There are two types of Tablets.

The first type is a screen with an Intel StrongARM processor, a FlashRom and a good amount of RAM (that is, a very powerful PDA).

The second type, sometimes called Convertible, resembles more a laptop; it seems a very versatile choice by joining some features of laptops (portability, practcality and power) with those of tablets (especially touch screen).

Almost all tablets are sold with preinstallation of Microsoft XP for Tablets. It is possible to install Linux on both types of tablets, rememebr to install also Xinput in order to use the touch screen as input device (non standard).

- On first-generation tablets, with StrongARM processors, the same distribution as for PDAs shall be installed, e.g. familiar
- On second-generation tablets, with Pentium III or greater, any version commonly used on a laptop may be used as well (redhat, slackware, debian, etc...)

Tablets are relatively expensive: some models available at project start are:

Model	**Features**	**Price**
	Toshiba Portege 3505 Processor Intel PIII 1.3Ghz 256Mb SDRAM HD 40Gb Modem, WLAN, Bluetooh, Ethernet	3800 Euros
	Acer Travelmate C102Ti Processor Intel PIII 800Mhz 256Mb SDRAM HD 30Gb Modem, WLAN, Ethernet	3000 Euros
	Fujitsu-Siemens Stylistic ST4110 Processor Intel PIII 800Mhz 512Mb SDRAM HD 40Gb Modem, WLAN, Ethernet	3000 Euros

Table 2: Tablets

Access Point and Router:

In the previous scenarios we have assumed a possible presence of AP (Access Point) and Router. Access Point may employ a point-to-point bridging, or point-to-multipoint.

Access Point may be uesd in various modes:

- Mode ACCESS POINT: the device extends the access to a wired LAN to wireless units. Wireless users within the radius of the access point may communicate with one another thru it.
- Mode WIRELESS BRIDGING Point-to-Point: the device can communicate with a specified remote WLAN.
- Mode WIRELESS BRIDGING Point-to-Multipoint: the device may communicate with other wireless bridges on the same channel and using the same ESS (Extend Service Set) ID.
- Mode ACCESS POINT CLIENT: the device may be used as a WLAN client. There should be another bridge acting as access point.

Routers may be considered like Access Points with added IP Routing functions. Routers may provide firewalling functions to protect the WLAN: IP filtering, socket filtering, NAT. Routers and Access Points of latest generation also support services like NAT/DHCP.

Both access point and router may implement either IEEE 802.11b or IEEE 802.11g protocols.In any case interprotocol communication is possible. Many models are commercially available to support these specifications.

The following table shows some models and their costs:

Model	**Features**	**Price**
	D-Link DWL 900AP Access Point IEEE 802.11b	162 Euros
	Asus AP Spacelink WL300 Access Point IEEE 802.11b	208 Euros
	Netgear MR914 Access Point/Switch/Broadband Router IEEE 802.11b	138 Euros
	D-Link DWL 2000AP Access Point IEEE 802.11g	N.A.

Table 3: AP/Routers

Peripherals analysis

Several accessories can be used in the scenarios of the project: the following is a list of some of them available at project start time:

Type	Model	Features	Price
CAM		Veo Photo Traveler For Ipaq series 3800/3900/5400	110 Euros
CAM		NexiCam NXC3100 For Ipaq series 3100/3600/3700/3800/3900/5400	200 Euros
CAM		Sharp Zaurus CF Digital Camera	280 Euros
WiFi Pcmcia Card		Asus WL100 pcmcia card 802.11b External Antenna	98 Euros
WiFi Pcmcia Card		D-Link DWL 650 802.11b	84 Euros
WiFi Pcmcia Card		D-Link DWL G650 802.11g	N.A.
GPS		Pocket GPS Navigator Serial link	300 Euros

GPS		GPS PCMCIA Card For Ipaq series 3100/3600/3700/3800/3900	250 Euros
Storage		Ipaq Memory Cards 32/64Mb	50/100 Euros
Storage		1Gb IBM Microdrive with PC Card Adapter	240 Euros
GPRS		Merlin GPRS Card Supplied with Linux drivers, Can be Two- or Tri-band	323 Euros
GSM/GPRS		Sierra Aircard 750 GSM/GPRS Tri-band	330 Euros
WiFi Pcmcia Card/GPRS		Nokia D211 802.11b GPRS	475 Euros
GSM		Ubinet GSM Card	115 Euros

Table 4: Accessories

Linux Drivers:

Except where specified, all these accessories are sold with Windows drivers only. All the others should be installed with specific drivers, not present in most Linux distributions for PDA (except on Zaurus).

In all cases the relevant drivers can be found on Internet, for example:

- GPS: we need a program to capture data and make it available to applications: we must install a gpsd daemon.
- WiFi Pcmcia Card: we need a driver for the chipset of our WNIC, the most widely used is Prism II. (see link)
- Modem/GSM/GPRS: they are handled like simple pcmcia modems.

Software analysis

Once a Linux kernel is running, any Linux software, in principles, can be downloaded to the above devices. However, especially on PDAs, their limitations suggest the use of systems especially designed for them, for example those based on Java. The mobility features present in JXTA are especially suitable. To develop software in C, it is better to use a cross compiler for StrongARM processors on a desktop; also many scripting languages are supported as well on PDAs.

JAVA:

On the Web we found a Java distribution called Blackdown, which is freely avaliable for Linux, with the following features:

- Fully Java 2 compatible
- Created for ARM Linux
- Freely distributed
- Support for AWT, SWING, RMI, JINI

The website, referenced in link, has downloads for J2RE 1.3.1 and JDK 1.1.8 distribution Blackdown.

There are other products like Kaffe, which do not appear to be fully compatible with Java, and may have some problems. We remark that Zaurus PDAs are distributed with PersonalJava 1.2 by Sun already installed.

Another useful Java Interpreter, frely available, is FIJI which is especially suited for Java component testing because of its GUI.

JXTA:

This project is al implemented in java, and aims at providing a set of protocols for mobile connectivity to the developers community. These protocols include P2P communications with cellular phones, or PCs.

JXTA creates a virtual network within each peer may communicate with the otherswithout worrying about firewalls, NAT or different transport protocols. The JXTA project provides examples (demos) for message exchange, group creation and file sharing, collected with the name InstantP2P.

For more information and downloads see the link section.

GCC:

Many Linux compilers and cross compilers for PDAs are available for the languages C/C++, including the most widely diffused one. GCC is distributed with GNU license and is available in optimized versions for StrongARM and XScale processors. The Zaurus has a preinstalled C/C++ compiler as well.

However for disk space limitations most applications should be developed on a desktop with a cross compiler. A cross compiler available for free is toolchain. However compiling and installing a cross compiler is a non trivial operation, so it is important to read the documentation by Intel available in the link section.

PYTHON:

Versione 2.2 is available for PDAs with StrongARM processors. For further information and downloads see the links.

Processors: StrongARM vs XScale

When PDAs emerged as common devices, almost each of them was powered by an Intel StrongARM processor. Later on, a new generation processor was launcehd by Intel, XScale, with the promise of improved performance. At the time of project start, both were present on the market so this section shows a comparison among them. XScale is a 32-bit RISC processor based on the ARM architecture. With respect to a StrongARM processor, an XScale processor has larger cache (64KB vs. 24KB) and a higher clock speed. At project start, the fastest commercially available processors were 400Mhz.

Size and power requests of an Xscale processor are about one third than those of a StrongARM one.

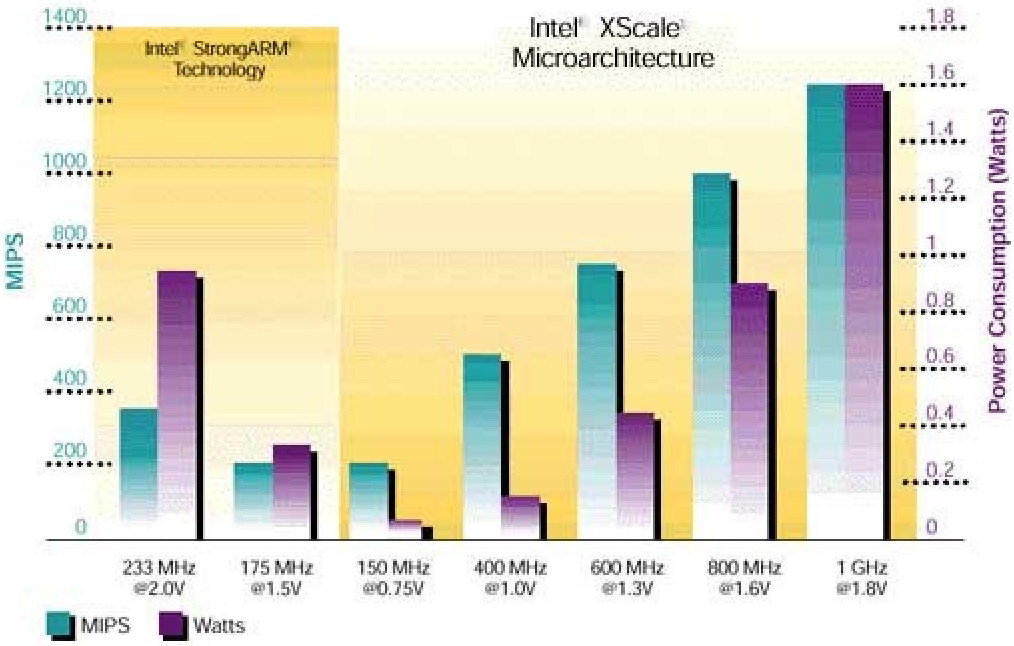


Figure 1: Power/Performance of StrongARM vs XScale

Benchmarks have shown that the performance improvement of XScale processors vs StrongARM ones is around 58% on floating-point and around 74% on integer computations.

Commercial device	Compaq iPaq H3850	HP iPaq H3950	Toshiba e310	Toshiba e740	Razor Zayo A600 Normal Mode	Razor Zayo A600 Turbo Mode
Processor	StrongARM 206 MHz	XScale 400 MHz	StrongARM 206 MHz	XScale 400 MHz	XScale 400 MHz	XScale 400 MHz
Floating point	8.05	12.66	8.02	12.66	12.66	12.67
Integer	15.54	26.94	15.49	26.94	26.97	26.97

Table 5: VOBenchmark Results

Since Summer 2002 Intel opened the SOC (Software Optimization Center) to encourage the development and use of optimized software for XScale processors, that is new software especially developed for their new features. Intel then made available online two libraries for software developers on XScale processors, both on Windows and Linux:

- **IPP** (Integrated Performance Primitives): cross-platform libraries, optimized for Xscale processors for multimedia applications, audio codecs, video codecs (including H263,

MPEG-4), image processing (JPEG), signal processing, voice compression (GSM ARM, G723)
- **GPP** (Graphics Performance Primitives): 3D routines optimized for Xscale processors

Of course all software develped for StrongARM is running also on XScale, but it does not make an optimal use of new processor features.

Since they have been introduced more recently, at the time of project start the price of Xscale-based PDAs was relatively higher with respect to the price of StrongARM based PDAs. However the various companies have progressively removed from the market those PDAs based on the older processor, the first one being HP. Sharp presented his Zaurus S5600 in Nov.2002 to substitute the previous models, to be available in spring 2003.

The suggestion at project start was to use a Linux PDA without paying too much attention to the problem of optimizing for one specfic model. By developing architecture independent software, the migration of possibly critical components to tablets or laptops would be eased in case some performance constraint is experienced on PDAs.

Protocols: 802.11g vs 802.11b

The following protocols were in wide use at the time of project start.

Protocols:

We consider both WiFi protocols and protocols for the coverage of geographic areas, since both could be interesting for the project.

Technology	**802.11b**	**802.11g**	**GSM**	**GPRS**	**UMTS**
Data Rate	11Mbps	54Mbps	9.6Kbps	30-50Kbps	256Kbps
Radius	100 m	100 m	10 Km	10 Km	100 Km
Frequencies	2.4Ghz (ISM)	2.4Ghz (ISM)	900/1800Mhz	900/1800Mhz	1900/2000Mhz
Standard	802.11	802.11	ETSI	ETSI	ITU

Table 6: protocol specifications

802.11g:

This protocol was quite recent at the time of project start. Here is a list of its main features:

- Bitrate up to 54Mbps at 2.4 Ghz
- Compatible with IEEE 802.11b, does not require more dense APs with respect to it
- Communication technique is OFDM - Orthogonal Frequency Division Multiplexing
- 3 non overlapping channels available- as in IEEE 802.11b

The implementation of IEEE 802.11g gives full upward compatibility with existing WLANs based on 802.11b, changing communication technique and speed. The first commercially available products supporting this protocol include D-Link products, PCI and PCMCIA wreless cards for 802.11g, Access Points and routers based on chipset PRISM (then compatible with previous software developed for the same chipset and 802.11b protocol). The implementation of WPA for secure communication is already available.

The presence of upward compatibility allows to develop transparent software development without worrying about the version (11b or 11g). However the applications which require high data throughput have a benefit with the use of 11g technologies.

In case a router is needed to connect various groups, we may assume that routers connect thru a 11g protocol to avoid router-router link congestion for its speed.

802.11b:

At the time of project start, this was the most widely used protocol for WiFi, and is progressively substituted by 802.11g. Its features are:

- Bitrate up to 11Mbps at 2.4Ghz
- Communication technique is CCK - Complementary Code Keying, DBPSK, DQPSK
- 3 non overlapping channels available

Systems software layer

On PDAs the choice of the systems software is towards Linux, distribution Familiar versions. This distribution allows more transparency in handling specific problems of these devices. For instance, it is easier to access all data about sensors and wireless transmission parameters. The same information is hardly accessible through Windows.

The section Link lists references to websites of the Familiar distribution and a search engine for finding the various software tools to be installed on such system.

Simulation tools

To evaluate the functionalities of a MANET, actual implementation of a mobile device network is often preceded by a series of simulations. Implementation is important, but very expensive, and tests are difficult to repeat, so simulation is important as well. Simulation requires the use of a suitable simulation system, in order to test software in several ad-hoc network environments and with different movements of mobile hosts

ns2 is an event driven simulator for mobile and fixed networks which was developed by the CMU/Monarch group. It has been used in a large number of projects to simulate networking topologies and to test protocols.
ns2 simulates each layer separately, including the physical layer, the MAC layer and the Link control layer. So it is possible to simulate all physical media features like delays, bandwidth congestion, error rate etc. By setting suitable simulation parameters. At a higher level, several environments can be defined, each one with different topology, node density, message traffic, movements in order to simulate protocol interaction, congestion, routing, or multicast as well.
ns2 has been implemented starting from the **ns** simulator (developed by DARPA and others, for the wireless part the major contributors were: UC Berkeley/Daedelus, Carnegie Mellon University/Monarch Project and Sun Microsystems). The extensions are organized as modules which may simulate Ad-Hoc networks, multi-hop networks and wireless LANs. The distribution package includes 4 implementations of MANET routing protocols: Destination Sequence Distance Vector, Dynamic Source Routing, Temporally Ordered Routing Algorithm e Ad-Hoc On-demand Distance Vector.

Other simulators can be found on the Internet, which can be downloaded at no cost (like ns2). It is worth mentioning among them the **MobiEmu** simulator, which is somewhat unique among them. In fact MobiEmu allows to simulate a mobile ad-hoc network environment on a fixed network, all machines running Linux. It is possible to define a mobile environment, in the same format as for ns2, which is simulated by putting a mobile node on each Linux fixed node, which will accept or reject messages received on the LAN in accordance with its simulated movements and connectivity. In this way a software application can be tested by executing it, in real time, on the fixed Linux network.

Inserire OPNET

Sensor networks

Hardware for Wireless Sensor Networks

This section introduces the main hardware platforms to implement wireless sensor network testbeds. These platforms can be roughly divided into two types. The first type includes those devices with high level computational power; the second type is that of devices with limited resources.

PC-104 devices

PC-104 is the result of a standardization effort performed by certain companies, in order to develop a bus to help interconnecting PC-compatible components in embedded environments. The aim of the project was to design a compact bus, to reduce the size of the devices on it, and to limit power consumption.
Devices based on PC-104 standard are usually rich in resources. Typical off-the-shelf components are CPUs with 400 MHz clock frequency, memory slots with several MB RAM (typically 16 MB), flash disk to store tens of MB of data. Unfortunately, at the time the project started there were no wireless communication peripherals already fully PC-104 compliant. However communication systems, based on Bluetooth or IEEE 802.11, can be integrated by suitable adapters. As for sensors, acquisition cards have been made available, with several analog inputs to to be connected to various sensors.
The diffusion of PC-104 products is due to the possibility of supporting software developed for desktops. Many testbeds include also a Linux kernel and traditional C libraries (e.g. glibc) running on these devices.

WINS

Another architecture, less modular but widely available as well, is the WINS devices built and sold by Sensoria Corp. (a company foundedn by two UCLA professors, Kaiser and Pottie). The present version of the product (WINS3.0) integrates an Intel PXA255 processor, with clock frequency ranging between 100 and 400 MHz, some tens of MB of memories, wireless communication peripherals (802.11b) and up to 16 analog input channels.
In this architecture as well it is possible to develop software on conventional desktops; in fact, WINS operating system is Linux. The system provides the developers with an API to ease access to hardware resources.

Processing and Storage

Main system processor	Intel PXA255 (scalable from 100 to 400 MHz)
Real-time DSP	TI TMS320VC5502
Main processor SDRAM	64MB
Main processor flash	32MB
Analog Sampling	
Number of input channels	Up to 16
ADC resolution	24 bits
ADC sampling rate	250-4000 sps
Peripherals	
GPS	12 channel WAAS-enabled GPS
Radios	Dual embedded 802.11b modules
Expansion interfaces	
RS-232 serial	5 generic + 1 Linux console
USB	2 host ports, 1 device port
Ethernet	10 Mbit
PCMCIA/CardBus	1 external slot
CompactFlash	1 external slot, 1 internal
Audio in/out	1 stereo input, 1 stereo output
Open Software Framework (OSF)	
APIs for sensing, power management, and networking	
Linux 2.6	
WirelessFabric™ networking technology	
Time synchronization for time stamped data	
Network health and status monitoring	

Motes

The term Motes is used to identify hardware platforms where a single card hosts the processor and the radio communication system. This card may directly interface to analog acquisition devices. Usually these devices have limited resources available: in comparison with the two previous architectures, software for Motes has to be carefully designed. The solutions developed should be aware of limitations in bandwidth, power supply, memory.

These devices contain slow processors (a few MHz) and small memories (some tens of KB). There may be different types of radio controllers. Some of them use transceivers operating on the ISM 916 MHz frequency, others are built in accordance with Bluetooth or 802.15.4 specifications, using ISM frequencies around 2.4 GHz. Some devices contain on-board sensors, others (most of them) have interfaces to connect to acquisition cards. The first choice allows a reduced cost and size with increased robustness of solutions, the second choice has much greater flexibility.

As operating system, Motes usually employ TinyOS, an event driver system based on components, developed by University of California, Berkeley.

	CrossBow MICA MPR300CB	**Moteiv Telos**
CPU and memory		
Speed	4 MHz	20 MHz
Flash	128 KB	256 KB
SRAM	4 KB	4 KB
EEPROM	4 KB	
Analog Sampling		
Number of input channels	8	0
ADC resolution	10 bits	
Performance		
Current drawn (active)	17.5 mA (5.5 cpu + 12 radio)	19 mA
Current drawn (sleep)	~ 20 uA	0.7 uA
Other features		
Serial comm.	UART	DIO, SPI, I2C, UART
Radio frequency	916 MHz	2.4 GHz
Data rate	40 KBps	250 KBps
Battery	2X AA	AA, 2/3 A, coin cell
Expansion connector	51 pin	not available

Software for Wireless Sensor Networks

Networking solutions especially developed for sensor networks must take into account the limitations on resources of these devices. The OSI model is not the best suited for classifying state-of-the-art protocols defined in current research projects. In fact many solutions take advantage of cross-layer design in order to solve problems at various levels. This meands that in order to solve a problem at a higher level, some information belonging to a lower layer may be accessed as well. Consider as an example a routing protocol which takes into account energy information from intermediate nodes before selecting the route. A second consideration is that the higher levels in the OSI model (especially the session and presentation levels) would cause an excessive overhead on these networks.

New reference stacks have been proposed, to properly model the requirements of Wireless Sensor Networks. An interesting model is shown in Figure 2: the major differences with respect to the OSI model are in the *Adaptive Topology* level, needed to save energy by putting to sleeping mode the redundant nodes, and in the *In-network Aggregation* level. The latter is important to perform fusion and data processing operations at intermediate nodes, along the information distribution path between data producers and consumers. In this way the amount of transferred data among participants is reduced, and this causes energy savings.

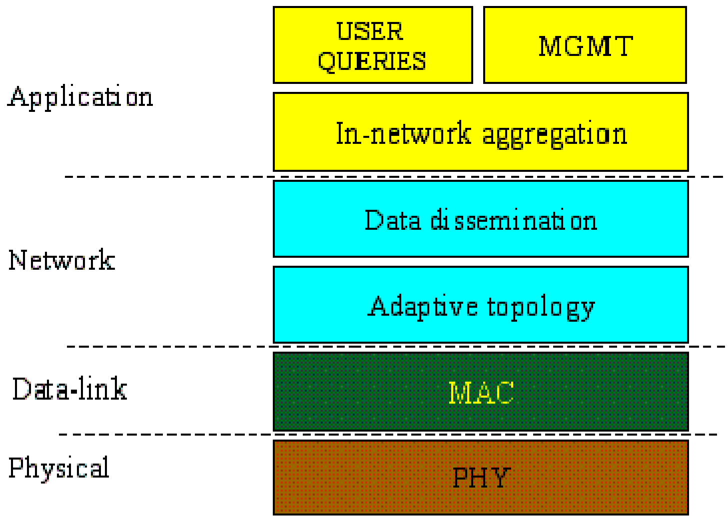


Figure 2: a reference model for the communication stack in Wireless Sensor Networks

Directed Diffusion

An advanced solution for remote sensor queries and data processing at intermediate nodes has been developed within the SCADDS project (Scalable Coordination Architectures for Deeply Distributed Systems) at the University of South California. The protocol they designed is based on a naming system based on application specific information. This choice is not a limitation, because sensor networks are seldom general purpose ones; rather, they are instantiated for a specific mission and tasks. On the other hand, this solution has two clear advantages. First, by using an unique naming system, we can avoid the overhead due to name resolution at different levels of abstraction. Second, in-network processing activation can be simplified, and is achieved by filters pre-installed at each node.

SCADDS project is ane experimental one, yet already reaching a remarkable degree of maturity. Code for Directed Diffusion is available as open source in several versions (see the Link section).

There is a version for the ns2 network simulator, and others for Linux (to be used on more powerful devices), and for TinyOS (to be used on smaller devices like Motes).

Link

Hardware

- http://www.zaurus.com
  Home Page of Sharp Zaurus PDAs.
- http://www.zaurus.com/dev
  Home Page of Zaurus developers.
- http://h20022.www2.hp.com/busprod/CatAtAGlance/0,,type=64929%5Ecategory=,00.html?lsidebarLayId=491
  Home Page of iPAQ PDAs.
- http://www.tablet-pc-shop.de
  Website which gives an interesting comparison of tablets, including features and prices (in German).

Software

- http://www.handhelds.org
  Home Page of the Linux Familiar distribution for PDAs.
- http://ipkgfind.handhelds.org
  Search engine for software running under Linux Familiar.
- http://www.lineo.com/products/embedix
  Home Page of the Linux Embedix distribution, currently installed on PDA Sharp Zaurus.
- http://www.jxta.org
  Home Page of the JXTA framework. (see details in the software analysis section)
- http://sourceforge.net/projects/fiji
  Home Page of the FIJI Java interpreter. FIJI allows to load, examine and execute classes and methods written in JAVA. It has a GUI and is distributed under GNU license. FIJI is useful for unit and component testing.
- http://www.blackdown.org
  Home Page of the Java Blackdown distribution for Linux. Notice the distribution for StrongARM processors.
- http://gcc.gnu.org
  Home Page of the well-known C/C++ compiler, available under GNU license.
- http://www.python.org
  Home Page of the Python library with manuals and useful development tools.
- http://starship.python.net/~hinsen/Zaurus
  Modules and additional software for Python especially developed for PDAs.
- http://www.intel.com/design/strong/applnots/sa1100lx/getstart.htm
  Intel's guide on how to download, compile and use a cross-compiler for StrongARM processors under Linux.

Simulation tools

- http://www.isi.edu/nsnam/ns/
  Home page of ns version 2.
- http://mobiemu.sourceforge.net/
  The MobiEmu Home Page

Sensor networks

- PC-104 (http://www.pc104.org)
  Homepage of the consortium dealing with bus standardization.
- WINS (http://www.sensoria.com/products-wins30.htm)
  Webpage of the latest product release (WINS 3.0).

- **Motes:**
  - Moteiv (http://www.moteiv.com/),
  - XBowMotes (http://www.xbow.com/Products/Wireless_Sensor_Networks.htm)
    Homepage of two main companies which build motes.
- SCADDS Univ.South California/Information Science Institute (http://www.isi.edu/scadds/)
  SCADDS deals with scalable architectures for coordination of highly dynamic distributed systems: it is an extremely mature project. The homepage lists documentation and downloads of protocols at different levels, among which there are various implementations of Directed Diffusion.
- SensoNet Georgia Institute of Technology (http://users.ece.gatech.edu/~weilian/Sensor/)
  SensoNet will implement protocols design and implementation at different levels.
- LEACH and SPIN Massachussets Institute of Technology (http://nms.lcs.mit.edu/projects/leach/)
  The project deals with two routing protocols: LEACH (unicast, proactive) and SPIN (multicast).
- COUGAR Cornell University (http://www.cs.cornell.edu/database/cougar/index.htm)
  COUGAR considers Wireless Sensor Networks as distributed database servers, and proposes extensions to the relational DB models. The website has a project demo.
- DataSpace Rutgers University (http://paul.rutgers.edu/~gsamir/dataspace/)
  This project proposes a novel concept of 3D space: DataSpace may be the Earth, the Galaxy or any other physical space. Each DataSpace is normally populated with objects which store and manipulate information about themselves.

Other Links

- http://www.hpl.hp.com/personal/Jean_Tourrilhes/Linux
  A collection of links to HowTo, Drivers, documents on security, all for Linux users.