The TINA Project –

A Portable Wireless Web Browser

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October 1998

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15th October, 1998

The Head
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Dear Professor Simmons,

In accordance with the requirements of the degree of Bachelor of Engineering (Computer Systems Engineering, Honours), I present the following thesis entitled "TINA The Internet Appliance – a Handheld Wireless Web Browser". This work was performed in partnership with Mr David Wilson and under the supervision of Dr Mark Schulz. I declare that the work submitted in this thesis is my own, except as acknowledged in the text and footnotes, and has not been previously submitted for a degree at the University of Queensland or any other institution.

Yours sincerely,

Michael Goddard

Abstract

This thesis describes the design and construction of a hand held wireless Internet Appliance designed for browsing the World Wide Web (called the TINA Project). The TINA Project improved on previous efforts by creating a device that was both totally portable and wireless. The TINA Project was built with latest generation components and techniques, using a built in radio modem to transfer data to and from the A4 sized device. The performance of the TINA Project at the time of writing was suboptimal, but possible remedies for the shortfalls have been presented. With slight enhancements the future of the TINA Project can be shown to be commercially viable in diverse fields such as process monitoring, medicine and electronic books.

Acknowledgments

Many thanks to those who made this project possible, including:

- David Wilson, my thesis partner
- Mark Schulz, for keeping us on track
- Marco Graziano and Teknema Inc, for donating the SA1100 CPU
- Rob Howe and Hawk Integrated Technology, for donating the LCD screen used in this project
- Micron Technology, for the sample 16MB SODIMM memory module
- Hideko Ono, of Berg Electronics Japan, for the sample SODIMM sockets
- Len Payne, for making us decide exactly what we wanted and what we needed, and for practical circuit design tips.
- Prof. Dennis Longstaff, UQ CSEE Department, and Michael Finney, of Uniquest, for their advice on Intellectual Property
- Geoff Walker and Sri Parameswaran for showing interest in the project
- Keith, Alan, and the rest of the crew at the Electronics Workshop, for helping us with the electronics construction on countless occasions, and letting me zap myself with an inverter
- Keith and Wayne in the Mechanical Workshop for helping us with the case design and construction
- Peter Ikladious, Christina Miller, Sharyn Efimoff, Jasper Chik, Carlos Gomez, Davin Briner and Andrew Over for providing feedback on our work
- My family, for proof reading and support

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1 Introduction

The rise of the Internet in recent years has caused major changes to the way information is communicated. The wide availability of information on the Internet has reduced the dependency of the general population on traditional sources of information such as newspapers, magazines and television, while greatly increasing the convenience of some everyday actions like checking bank records. People who would not previously have pursued knowledge because of the inconvenience are now using the Internet to learn from the comfort of their own home, workplace or café.

As well as greater access to information, the Internet is providing a range of services that users can take advantage of, such as personal communication, online shopping, electronic bill payment and other forms of electronic commerce. Indeed, e-mail is now the preferred personal communication method of many people due to the speed and convenience of this medium. In the future, the Internet will be of even more importance than currently.

1.1 The Future of the Internet

The future of the Internet is as hard to predict now as it has ever been. Even a few years ago, the capabilities and reach of the modern Internet were undreamt of. The Internet and the World Wide Web have entered the consciousness of modern society, with online commerce becoming commonplace. Despite these rapid changes, several likely features of the future Internet can be selected for further elaboration. These features are ubiquity, convenience and security.

1.1.1 Ubiquity

In the future, the Internet will be even more pervasive than it is now. The use of web sites and e-mail is booming and examples abound:

- Commonwealth Games Coverage [51]
- Political Propaganda [33,4]
- Electoral Results [3]
- Movie Websites [18,24]

- On-line shopping (including groceries) [62,21]
- On-line banking [59]

This seemingly exponential expansion of use will be helped by the fact that the Internet will be accessible everywhere – rudimentary Internet terminals are already being installed in public places, Internet access is being offered in hotels [10], Internet cafés are booming, and everyday appliances and objects are being connected to the Internet to enhance convenience and to notify owners when maintenance is needed. Several major Information Technology companies, including IBM, Toyota and Boeing [11], are working to add Internet access to motor vehicles and passenger aircraft. Mobile phone manufacturers are already designing enhanced mobile phones capable of accessing Internet information [57]. In the near future, the Internet will be available to people wherever they go, quickly and simply.

1.1.2 Convenience

The future Internet will be even more convenient than it is now. The previous section outlined some of the benefits of increased Internet coverage. One of the major areas where users are enjoying greater convenience is that of Internet shopping – Internet commerce is expected to exceed US$350 billion in five years time [35].

Even in the near future, Internet use will grow to the point where it will be more convenient to consult a web page than to leave the house to perform tasks. It will be possible to vote over the Internet [63], view movies over the Internet, buy clothes and groceries [62] over the Internet and have them delivered, and pay your utilities bill, all from the comfort of your own web browser. Already on-line merchants like Amazon.com [5] have outgrown their physical brethren to provide their wares to customers all over the world.

1.1.3 Security

One of the emerging problems of the Internet, particularly when facilities like Internet Banking and on-line shopping are involved, is that of security [31]. In the early days of the Internet only simple security was necessary. These days much more elaborate security measures are needed, particularly with the falling costs of hardware required to ‘crack’ the security. In the future, a large proportion of Internet transactions will be of a secure or sensitive nature, so even better security will be required. In particular, wireless access to the Internet needs to be secure since (as with mobile phones) the signal may be intercepted relatively easily, and this means some encryption scheme is necessary.

1.2 The TINA Project Vision

The features of the Internet discussed earlier gave rise to a vision of a portable web browser capable of securely accessing the Internet. This device would allow convenient access to the Internet from a wide range of locations. In previous years a basic web browsing platform was created by Ben Williamson [60] and Craig Newell [47]. In 1998 the TINA team, Michael Goddard and David Wilson, extended the previous projects (called the Netslate Project [60,47]) to become more focussed on portable wireless web browsing. The TINA Project is intended to allow convenient secure access to the Internet for users of all skill levels, uses a secure wireless data link, and is designed especially for Internet use, with no confusing lap top controls or expensive unnecessary features.

With this focus in mind, the TINA project will meet some of the projected needs of the future Internet user – it is portable to provide ubiquitous access; users can browse the Internet easily as soon as the device is turned on; and all network transactions can be encrypted to provide security.

1.3 TINA Project Achievements

During the course of the TINA Project, there were several major achievements made under the constraints of time and budget of an undergraduate thesis. Two pieces of hardware were produced in the project's lifetime: the wireless base station, called NINA (described in Sections 4.3 and 5.1.2), and the portable web browser (shown in Figure 1), dubbed TINA (described in Sections 4.2 and 5.1.1). A short summary of these achievements is presented to allow the reader to keep these in mind while reading the rest of the thesis document.

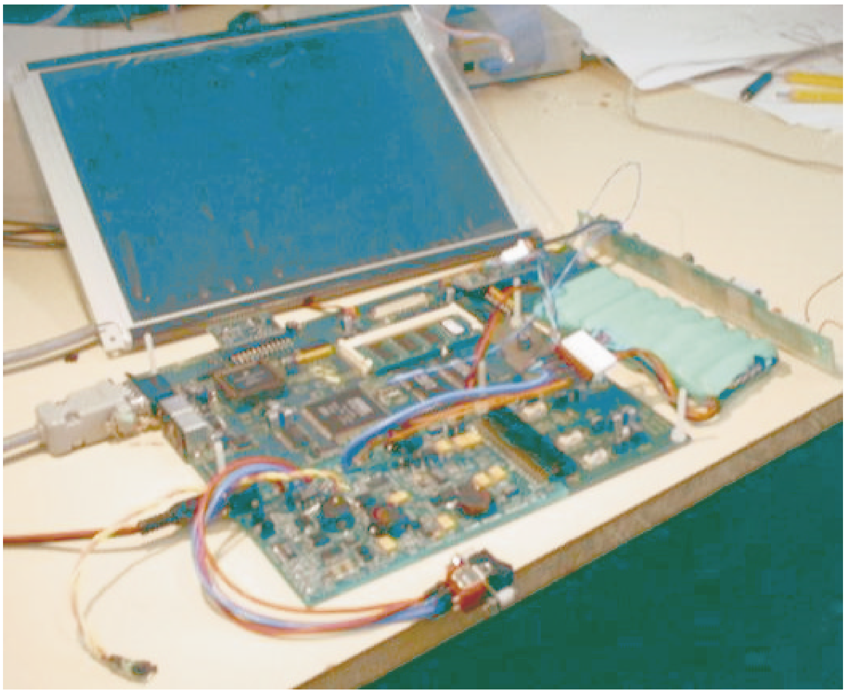

Figure 1 - TINA Project Hardware

- Wireless Base Station, capable of 50 kilobits per second data transfer
- Portable Web Browser running the Inferno Operating System [40] from Lucent Technologies, with the following features:

  - Relatively small dimensions (roughly A4 in area, and 36 mm thick – See Appendix A)
  - Colour 10.4” LCD Display, with touch screen
  - Wireless network support
  - Secure Network Operating System (Inferno), with several applications including a web browser, an e-mail client and several demonstrations
  - Support for PS/2 Mice and Keyboards
  - 200 MHz Digital StrongARM SA1100 Microprocessor
  - 32MB of Low Power EDO RAM and 4MB of Low Power Flash EPROM
  - Sophisticated Power Supply, including battery charger and monitor
  - Two layer PCB construction

1.4 Thesis Document Structure

Following the introduction, a review of the features of current Internet Appliances is presented, followed by a summary of the desired specifications for the TINA Project based on this information and the features of the future Internet. The implementation of the TINA Project is then discussed in general. Detailed implementation information is unfortunately not provided in this document due to patent and disclosure considerations.

A review of the performance of the TINA Project at the end of the project lifecycle follows, along with a comparison of the final specifications versus the specifications derived in a review of existing Internet Appliances. A discussion of the future of the TINA Project is followed by the conclusions drawn from the TINA Project.

2 Internet Appliances – A technology review

There are many devices both on the market and in the research labs that are intended to be used with the Internet or other information sources. In order to establish desired specifications for the TINA Project several of these devices were reviewed in terms of the features described in Section 1.1.

2.1 Notebook Computers

Notebook computers are a burgeoning market that fulfil many of the objectives of the TINA project. Unfortunately for many people, they are too complex, and are more capable than required. Notebook computers can certainly be used as Portable Web Browsers, but they can also be used for other unrelated tasks like word processing and spreadsheet calculations. These extra features usually contribute to a higher cost which prevents them gaining universal acceptance.

Two notebooks were compared in this literature review: the Toshiba Libretto 70CT, and the NEC Versa SX.

2.1.1 Toshiba Libretto 70CT

The Toshiba Libretto [58] series of miniature notebooks are extremely small notebooks capable of running Microsoft Windows 98. These notebooks are roughly the size of a VHS video cassette, yet pack normal notebook equipment like hard drives and PCMCIA slots. The Libretto series are definitely convenient, as they weigh under one kilogram but have a high resolution active matrix LCD screen. Since they are essentially normal IBM compatible PCs, the Libretto series can use a large variety of peripherals and Internet applications, which would allow the Libretto series to fulfil the vision of the Future Internet.

Figure 2 - Toshiba Libretto 70CT

2.1.2 NEC Versa SX

Figure 3 - NEC Versa SX

These high end notebooks have the latest Intel Pentium II processors, large active matrix displays, and very large amounts of storage space. With an appropriate wireless networking adaptor these notebooks would be perfectly capable of performing any Internet task desired, but these notebooks are vastly more capable than most people need or desire. This technological excellence comes at a hefty price, with the base model starting at US$3100 [46]. These notebooks possess most of the features outlined in Section 1.1, but are not cheap or light enough to enjoy ubiquity.

2.2 Electronic Books

Electronic Books, or e-books, are a relatively new product. E-books are intended to replace normal paper books with an enhanced electronic book that can perform additional functions like text searching and bookmarks [12]. There are very few e-books actually on the market, with most models planned to be introduced over 1999 and early 2000. E-books are quite similar to the TINA Project vision of a portable information browser, with the emphasis for TINA on web pages instead of electronic books. During the initial product review process, there was very little information on e-books available, but over the course of the year more manufacturers released information about their products. Several different products are reviewed in the following sections.

2.2.1 EveryBook Dedicated Reader

Figure 4 - The EveryBook Dedicated Reader

The EveryBook Dedicated Reader [14], not yet released, is meant to be a close approximation to a real book. It has two high resolution colour LCD panels mimicking the two facing pages of a book. The Dedicated Reader has some built in Internet connectivity, but unfortunately it is not wireless. Apart from this lack, the Dedicated Reader could be used as a portable web browser, although the two screens would make it slightly unorthodox. The Dedicated Reader can even run Windows 98, so compatibility with the latest Internet software is assured. The main drawback to this product is the high cost - US$1500.

2.2.2 Librius Millennium

The Librius Millennium [34] is an electronic book aimed at the low cost, high volume market. Estimated to sell for under US$300, the Millennium is a light, easy to use information browser. The Millennium has no built in Internet access, relying upon a host computer to provide the electronic book titles over a serial link. The Millennium also uses a greyscale LCD screen, which does not really do justice to modern web pages. The Millennium is an interesting device that fulfils some of the TINA vision, but ultimately not all. The best thing about the Millennium is the physical packaging – this is quite a comfortable design.

Figure 5 - Librius Millenium

2.2.3 SoftBook Press SoftBook

Figure 6 - SoftBook Press SoftBook

The last e-book reviewed, the SoftBook Press SoftBook [53], is similar to the Librius Millennium. It has a greyscale display, and can store up to 100,000 pages. Similar to the Librius Millennium, the SoftBook does not have direct Internet access, instead using a built in modem to dial up a special electronic bookstore. The lack of a colour display and wireless networking makes the SoftBook inappropriate for a portable web browser, but as a general information browsing tool, the SoftBook is adequate.

2.3 Personal Digital Assistants and Palmtops

The Personal Digital Assistant (PDA) market is a relatively new and rapidly expanding one. These devices are usually small enough to fit in a pocket or a purse, and offer features ranging from contact management to word processing. As such, they are very convenient to the everyday user. There are two major divisions in this market – PDAs at the low end, and Palmtops at the high end. Palmtop computers range from stripped down notebooks like the Toshiba Libretto reviewed in Section 2.1.1, to calculator sized devices like the Sharp Mobilon, reviewed below. PDA devices were originally termed electronic organisers, storing phone numbers and appointment information. Recent trends in the PDA market have added features like handwriting recognition, blurring the distinctions between palmtops and PDAs. One of each of these devices was reviewed: the 3Com Palm III and the Sharp Mobilon HC-4500.

2.3.1 Sharp Mobilon HC-4500

Figure 7 - Sharp Mobilon HC-4500

The Sharp Mobilon HC-4500 [52] is a Windows CE based palmtop with a colour LCD screen. It comes with a Web Browser (Microsoft Pocket Internet Explorer) and a built in modem, so it allows portable web browsing, and wireless web browsing using Infra Red. Unfortunately this limits the wireless range of the HC-4500 to a few metres, which is not particularly convenient. The HC-4500 has a touch sensitive colour LCD screen, as well as a small keyboard, so the device is fairly easy to use. Ease of use is an important requirement for a popular device.

2.3.2 3Com Palm III

The 3Com Palm Pilot series of handheld computers is one of the most popular handheld computers on the market. They offer time and contact management software, as well as e-mail. The Palm Pilot series uses a touch screen and a handwriting recognition scheme called “Graffiti” [1] that allows the user to enter data quickly. The Palm III is the latest in the Palm Pilot series, and retails for around US$370 [2]. The Palm III does not offer wireless networking, but is still a very easy to use device, which is no doubt a major reason why they are so popular.

Figure 8 - 3Com Palm III

2.4 Slate Computers

Slate computers are a type of PC that have met with mixed success in the past. Similar to e-books, they are quite similar in shape to a clipboard with an LCD screen. Most slate computers take the clipboard analogy further, with a pen or stylus used to write on the touch sensitive screen. Slate computers are quite popular in the industrial market, with Fujitsu, one of the major manufacturers, selling over US$75 million in 1996 alone [48]. Slate computers allow the user to hold the computer with one hand and enter data with a stylus in the other.

The convenience of the slate computer means that they could be used to browse the Internet quite easily. Most slate computers are compatible with normal IBM PC computers, even to the point of running Microsoft Windows 95 or Windows NT. Several slate computers were reviewed, including the precursor to the TINA Project, the Netslate.

2.4.1 Netslate

The Netslate, Ben Williamson and Craig Newell's thesis project, is a variety of slate computer, but unlike most, the Netslate does not have a touch sensitive screen, relying instead on an external keyboard and mouse to be plugged in. This reduces the convenience of the slate computer format. Apart from that, the Netslate project was a good attempt to produce a hand held web browser. The Netslate needed several cables to function, including power and until 1997, a serial cable to provide Internet connectivity [47]. As such, the Netslate was not the portable, wireless web browser envisioned in Section One, but the groundwork was laid for the TINA Project.

Figure 9 - Netslate 97

2.4.2 Telxon PTC-1194

Figure 10 - Telxon PTC-1194

The Telxon PTC-1194 [56] is a slate computer based on a normal IBM PC compatible notebook. It also offers several options for wireless networking. The PTC-1194 runs Microsoft Windows 95 or Windows NT, so any of the more popular web browsers will run on it. The only drawbacks to this product are cost and availability: since they are mainly intended to be an industrial product they are more expensive and rare.

2.4.3 Fujitsu Stylistic

The Fujitsu Stylistic [16] is another industrial pen based computer, similar to the Telxon PTC-1194. It is PC Compatible, running Windows NT, and is available with integrated wireless networking. Again, since the Stylistic is intended for industrial use, it is considerably more expensive than normal consumer products, which is its chief drawback.

Figure 11 - Fujitsu Stylistic 1200

2.4.4 Sharp Mobilon TriPad PV-6000

Figure 12 - Sharp Mobilon TriPad PV-6000

The TriPad PV-6000 [52] is a consumer oriented slate computer. It has a stylus based touch screen, but also has a 64 key keyboard attached. The TriPad has wireless networking options to allow roaming access to the Internet, and runs Microsoft Windows CE so that support for new Internet standards is assured. The TriPad is more convenient for normal users than the previous slate computers discussed because it is aimed at the business market instead of the industrial market, so the TriPad is closer to fulfilling the features proposed in Section 1.1.

2.5 Summary of Internet Appliance Review

The previous reviews highlighted the importance of convenience in a successful product. The most successful products are the ones that offer the user a more convenient method than was previously available. Even products that are technologically inferior sell well if they are more convenient than their competitors. One important point is that many of these devices perform far in excess of the demands most users place upon them, so any extra cost or development time spent on improving the technology rather than the convenience is wasted.

Another interesting point is that many of the devices reviewed featured touch screens as the primary input method. Touch screens allow people with very little computer experience to interact with the computer in an intuitive way, thus ensuring that they have wide appeal.

Despite the convenience of these products, the portable web browser market is not well served at the moment, with most products offering either web browsing or portable network access, with only the most expensive offering both. The specifications for the TINA Project (described in Section 3) were developed with these shortfalls in mind.

3 Derivation of the TINA Product Specifications

After the review of existing "Internet Appliances" presented in Section 2, a set of reasonable specifications and guidelines for the TINA project was derived. These were determined both from the summary of current generation products and the expectations of the Internet of the future, presented in the introduction. Since the TINA Project is meant to represent the future of the Internet, the specifications are based more on these expectations, yet still tempered with the limits of current technology. Each major aspect of the future Internet and the specifications derived from that are presented, followed by the restrictions that current technology places on the project.

3.1 Ubiquity

For the TINA Project to contribute to the ubiquity of the future Internet, it must be usable in a wide range of locations. This implies that the TINA Project will be portable, if not hand-held, in order to allow its use everywhere. The range of locations also necessitates that the TINA Project be robust enough to cope with everyday use and environments. To truly facilitate common use of the TINA Project, it should be wireless so that ungainly cables do not limit the movement of the user. This criterion simply means that the TINA unit should be stand alone with no external power or Internet access cables to limit the user. Finally, to gain wide acceptance the TINA Project should be reasonably cheap, both to buy and to service.

In summary, designing for ubiquitous use means that the TINA Project should meet the following guidelines:

Specification	Reason
Wireless	No cables to limit range of use
Internal Power Supply	Ensure Portability
Internal Network Access	Ensure Portability
Hand Held	Easy to carry between locations
Cheap	To gain wide acceptance
Robust	To withstand everyday use

Table 1 - Summary of Ubiquity Design Specifications

3.2 Convenience

Convenience is perhaps the most important design factor for the TINA Project. In order to become ubiquitous, a device must first be more convenient than the alternatives. This is shown by the proliferation of Automatic Teller Machines and fast food merchants.

To allow the TINA Project to be used in a large range of locations, the TINA device itself must lend itself to this use. This means that the device must be portable – it is not convenient to lug around a heavy terminal. Two corollaries of this requirement are that the TINA Project must be lightweight and comfortable. There are other design choices to be made that increase physical convenience. Two of the most important deal with the interface with the user – the user input method and the display. To this end, it is important to have an intuitive input method (such as a touch screen or voice recognition), as well as a convenient output method (readable in a wide variety of lighting and environmental conditions).

The best user interface and case design alone would not make the TINA Project a successful embodiment of the future Internet. Other factors apart from the physical influence the convenience of the TINA Project. Some of these factors have already been taken into account in the section on ubiquity, but the quality of the software also affects the convenience of the product.

Specification	Reason
Light weight	Easy to carry
Comfortable	Easy to hold and carry
Good Display	Reduce eye strain, increase quality of use
Instant On	Allow instant use
Intuitive Interface	Simplify use, appeal to a broader market
Compatibility	Allow use with standard Internet technology
Long Battery Life	Reduce need for recharging stops

Table 2 - Summary of Convenience Design Specifications

3.3 Security Implications

As the Internet is used more for financial transactions, information security will be of the utmost importance in the future. To meet this need, any Internet Appliance needs to be able to prevent unauthorised users from intercepting confidential data. To this end, the TINA Project needs to be able to encrypt any wireless data, since by their very nature wireless communications are meant to be indiscriminately broadcast. Another area where encryption needs to be employed is that of secure World Wide Web transactions (such as the Secure Sockets Layer standard [22], or SSL). Many on-line stores and banks rely on this type of transaction, so the TINA Project Web Browser needs to support these types of secure transactions.

In addition to the security of information, the security of the actual physical hardware is important. Since the TINA Project is intended to be easily portable, prevention of theft is quite difficult. The only practical measure possible is to ensure that only specific users can authenticate themselves to use the TINA Project, thereby making it useless, and thus less desirable to thieves. This is similar to the approach taken by mobile phone manufacturers.

In summary, the following specifications are necessary to ensure security:

Specification	Reason
Encrypt radio traffic	Prevent interception of data by third parties
Support secure transactions	Permit safe on-line commerce and secure databases
Authentication	Prevent unauthorised use and deter theft

Table 3 - Summary of Security Design Specifications

3.4 Limits of Current Technology

Despite the requirements of the future Internet, it is today's technology that the TINA Project must employ. This places a number of limits on the development of the TINA Project. Foremost among these is cost, since there is only a limited budget for the development of the TINA Project at a university. Indirectly and directly this affects the choices made. The other significant limitation on the development of the TINA Project is time, since the timeframe is limited to less than a year, so any delays in receiving components need to be planned for. The effect of these major limitations on the choice of hardware is explored in more detail in later sections. Current technology for wireless data transfer is not well developed, with severe trade-offs between speed, range and cost. Batteries are another area where severe limitations exist, since most consumer grade batteries are not particularly well suited to use in the TINA Project. Program space, which places a limit on the complexity of both the applications and the content viewed using the TINA Project, is another critical problem, as is the processing capability of the CPU. One major limitation on the complexity of the TINA Project hardware is the cost of printed circuit boards, because prices escalate sharply with the quality and intricacy of the circuitry.

Specification	Reason
Budget	Limited Resources
Time	Duration of Undergraduate Thesis Project
Network Bandwidth	Cost, Radio Frequency Licensing
Battery Life	Cost
Speed of processor	Cost
Storage Space	Cost
Printed Circuit Boards	Complexity, Cost

Table 4 - Summary of Current Technological Limitations

3.5 Summary of Specifications

The following table (Table 5) summarises the previous tables

Specification	Aspect	Reason
Wireless	Ubiquity	No cables to limit range of use
Internal Power Supply	Ubiquity	Ensure Portability
Internal Network Access	Ubiquity	Ensure Portability
Hand Held	Ubiquity	Easy to carry between locations
Cheap	Ubiquity	To gain wide acceptance
Robust	Ubiquity	To withstand everyday use
Light weight	Convenience	Easy to carry
Comfortable	Convenience	Easy to hold and carry
Good Display	Convenience	Reduce eye strain, increase quality of use
Instant On	Convenience	Allow instant use
Intuitive Interface	Convenience	Simplify use, appeal to a broader market
Compatibility	Convenience	Allow use with standard Internet technology
Long Battery Life	Convenience	Reduce need for recharging stops
Encrypt radio traffic	Security	Prevent interception of data by third parties
Secure Internet Transactions	Security	Permit safe on-line commerce and secure databases
Authentication	Security	Prevent unauthorised use
Budget	Technology	Limited Resources
Time	Technology	Duration of Undergraduate Thesis Project
Network Bandwidth	Technology	Cost, Radio Frequency Licensing
Battery Life	Technology	Cost
Speed of processor	Technology	Cost
Storage Space	Technology	Cost
Printed Circuit Boards	Technology	Complexity, Cost

Table 5 - Summary of TINA Project Specifications

In summary, the TINA project is an attempt to create a sophisticated web browsing platform that will allow a broad range of people to access the Internet securely from a wide range of locations. The specifications aim to describe a product which will fulfil the needs of future users of the Internet, but which will be constructed with present technology. Convenience is a major emphasis of the project, since users are prepared to forego some features in favour of convenience.

4 Implementation of the TINA Product

There were several stages in the TINA Project lifecycle. In the beginning, the initial concept was discussed and expanded, and initial product research was conducted. During this research period, several existing products were reviewed (previously covered in section 2). Following the derivation of the specifications presented in Section 3, initial design work was performed to determine the basic system architecture. This initial design is presented next, followed by more detailed information on the system design.

4.1 Initial Implementation Decisions

From the specifications previously given, it was necessary to decide how to implement the project to meet those specifications. Since the TINA vision is for a totally wireless, easily portable web browsing device, several basic design choices were made based on the specifications:

- Light weight (Reduce amount and size of circuitry)
- Portable Power supply (eg. Batteries or Solar Panels)
- Wireless Communications (eg. Infra Red or Radio Frequency)
- Colour display of reasonable size
- Built in controls (eg. Touchscreen, Track Ball, Touch Pad etc)

There was also a fundamental choice between what might be called a remote terminal – little local intelligence but a fast network link, and an intelligent local device with a slower network link. The former choice is closer to the model presented by Network Computer (NC) [54] proponents, and the model implemented by Ben Williamson in Netslate 96 [60]. The use of remote intelligence allows the hardware to be simpler, but places a greater strain on the wireless data link, since all program data must travel over the data link, in addition to the graphical data.

The other alternative, that of having local intelligence, allows more of the processing to be performed internally. This means that the only data that needs to travel over the wireless data link is the graphical information (web pages, images etc) that need to be displayed. This approach is more versatile, but comes at the expense of extra hardware – a faster CPU and larger local storage space to contain programs and data are required. Both of these alternatives were investigated, but the final decision was the local intelligence option, for the following reasons:

- Greater versatility
- Capability of being used away from the network
- Fast Network links are expensive and hard to obtain
- Fast CPUs are not much more expensive than slow CPUs
- Large semiconductor storage devices are available cheaply

Having made this choice, the basic system structure was designed. Since the TINA Project is intended to be mobile and wireless, some type of base station that is connected to a fixed network is required. With this choice of network architecture, the TINA Project structure is illustrated in Figure 13:

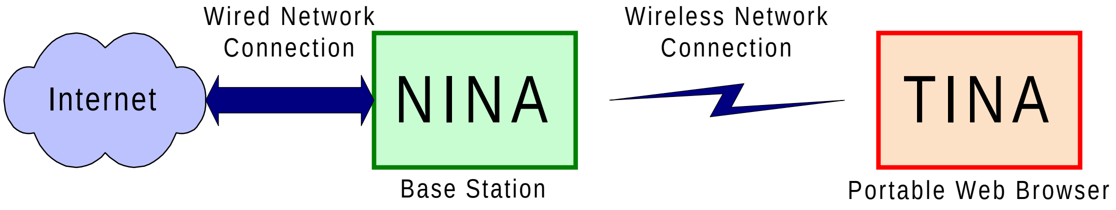

Figure 13 - TINA Project Overall Structure

Note that the principal component of the system is the portable web browser module. This module was designated the *TINA* module, since it is the largest part of the TINA Project thesis. The Base Station was designated *NINA*, to fit in with the naming scheme. The detailed design of both major modules, *TINA* and *NINA*, is presented next.

4.2 Web Browser Implementation – The TINA Module

Having defined the basic product (as described in Section 4.1), the following hardware and software sub-sections required to implement a portable web browser with local intelligence were identified:

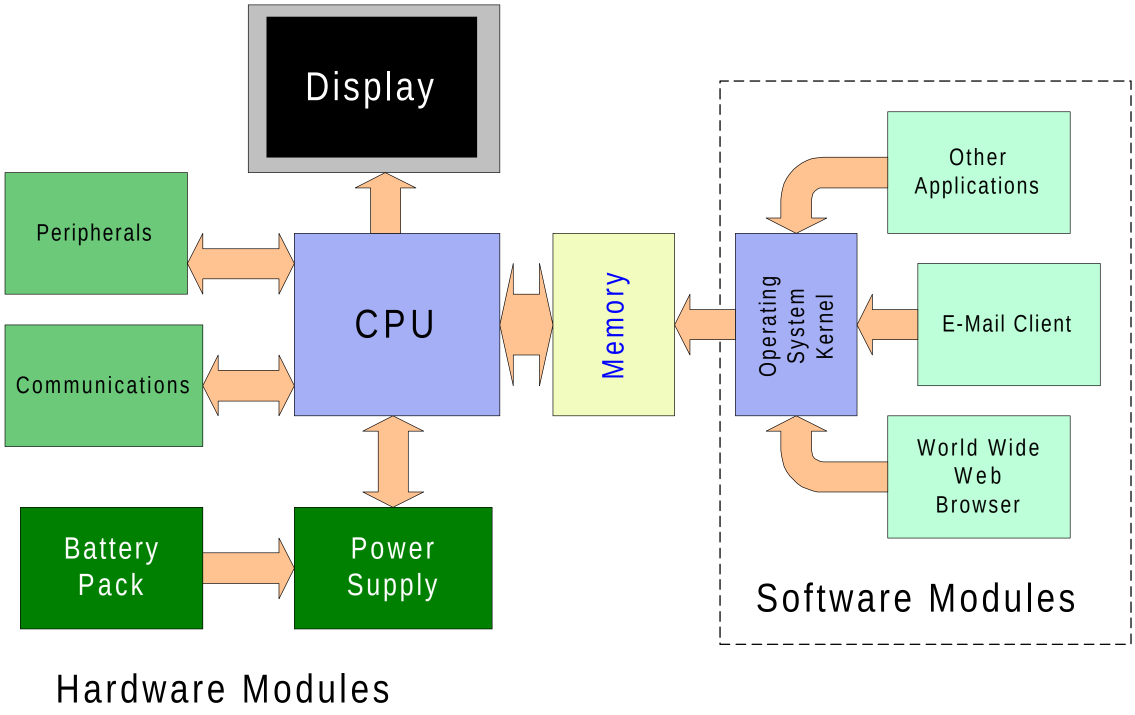

Figure 14 - Block Diagram of TINA module

Hardware:

- Display
- CPU
- Memory
- Communications
- Peripherals
- Power Supply and Battery Charger

Software:

- Operating System
- Web Browser
- E-Mail Client
- Other Applications

These sub-sections are discussed individually in the following sections.

4.2.1 Hardware Modules

The hardware implementation was considered first, to allow for delays in construction. For each of these sub sections, a cycle of research and basic design, followed by extensive searches for sources of components, was followed. After obtaining components, circuit boards were designed, constructed and finally tested. The modules are grouped into two separate circuit boards – a power module with the voltage supplies and battery charger on it, and a motherboard with the remaining circuitry on it. The decision to produce two separate circuit boards was made at a time when all of the voltage requirements were known, but most of the motherboard circuitry was undecided, which allowed some of the hardware to be designed, constructed and tested while design of the motherboard was continued. The implementation of each of the modules is described, followed by a description of the circuit boards produced for the TINA module.

4.2.1.1 CPU

The correct choice of a CPU was critical to the success of the project. There are many sophisticated CPUs available today, and a good choice would simplify the hardware and software for the rest of the project. For these reasons, the choice of CPU was made first. Several CPUs were reviewed in terms of the following features:

- Performance – Is it possible to run a web browser easily?
- Software Support – Is it possible to get development tools (compilers, assemblers etc) easily?
- Availability – Is it possible to obtain small quantities of the CPU in Australia?
- Ease of Design – Is it possible for two undergraduate engineers to design a successful implementation?
- Integrated Peripheral Support – Does the CPU contain any additional features (like a DRAM controller) that would simplify the design?
- Physical Shape – Does the CPU require finer tolerances than available?

Based on these criteria, several modern CPUs were investigated, including the Digital StrongARM SA110 [26] and SA1100 [27], the Motorola 68HC332 [43], and several

PowerPC variants [25]. Of all these chips, the Digital StrongARM SA1100 was chosen for the following reasons:

- The SA1100 is available in a 200MHz version, achieving 230 MIPS [27], thus guaranteeing enough performance for a web browser.
- The StrongARM family of chips is based on the very popular ARM architecture [6] – good development tools abound for this architecture, including several free utilities like compilers and debugging tools [8,7].
- Due to the kind assistance of Teknema Inc [55], two sample SA1100 chips were donated to the TINA Project, thus solving the availability requirement.
- There are several reference designs available for the SA1100, and the datasheet [29] for the part contains several helpful circuit designs, thus aiding a successful design.
- The StrongARM SA1100 is targeted squarely at the burgeoning low cost "Internet Appliance" market – it is a low power CPU with extensive integrated peripheral support.

The SA1100 has logic on-board for the following functions:

- EDO DRAM controller which allows the designer to simply connect a DRAM module to the CPU, with all addressing and refresh cycles generated automatically by the CPU.
- LCD Controller – this function of the SA1100 is one of the most important. LCD displays are not simple to control, and the integration of this logic into the CPU not only reduces the total hardware required, but simplifies the software interfacing. The SA1100 LCD controller supports several different types of LCD screens, both active and passive.
- Several on-board UARTS for serial transmissions. The SA1100 supports IrDA transmissions, USB, several PC compatible UARTS, and a number of multimedia serial formats.
- An abundance of "general purpose" inputs and outputs, to allow control of additional peripherals.

- The SA1100 is available in a 208 pin Thin Quad Flat Pack (TQFP) with 0.5mm pin spacing. While this package is not the most convenient to use, requiring some rather fine circuit board tolerances, it was possible to design and implement a circuit board based on this package, described in section 4.2.2.4.

For all these reasons, the SA1100 was an ideal choice of CPU for the TINA Project.

4.2.1.2 Display

The display is one of the most critical areas of the TINA project – since the World Wide Web is predominantly graphical, a good web browser needs to have a good display. The criteria used for the TINA Project to determine the best display are as follows:

- Portability of Display
- Compatibility with the Digital SA1100
- Size of Display
- Quality of display
- Cost and availability of Display
- Power consumption
- Weight

Due to the first criterion, there is only one family of displays that is practical – Liquid Crystal Displays. These displays are available in thousands of different sizes and quality, but they are generally classified into two types – Active Matrix Thin Film Transistor (commonly called TFT) Displays, and Single/Dual Scan Super Twist Nematic (usually just called STN or DSTN displays, or passive displays). The SA1100 CPU can control both types with equal ease, so the second criterion was met.

TFT displays give a superior picture, and are commonly used in higher end notebook computers. In addition, TFT displays are usually at the cutting edge of technology, incorporating many convenient features like backlight power supplies internally. Unfortunately, TFT displays are significantly more expensive than an equivalently sized passive LCD screen. In addition, the only practical source of TFT displays in Australia is through the notebook repair channel, and the vendors contacted were unwilling to provide data or even prices since there was no actual service being performed. These problems led to the choice of a passive matrix screen for the TINA Project. This screen (shown in Figure 15, along with the touch screen), donated by Rob Howe of Hawk Integrated Technologies, is a modern passive matrix screen with a resolution of 640 by 480 pixels, and a diagonal size of 10.4 inches. The display is quite light, and the power consumption is fairly low.

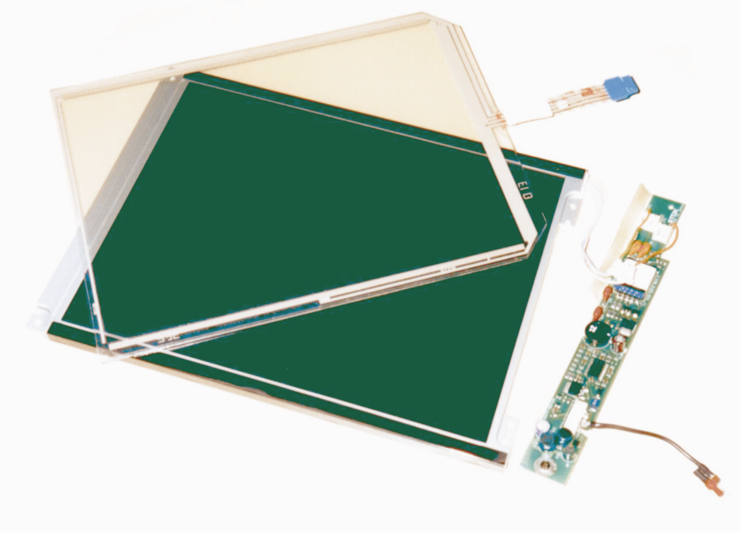

Figure 15 - TINA Project LCD and Touch Screen

4.2.1.3 Memory

There are two requirements for memory in the TINA device – the non-volatile program storage space, and the volatile temporary data space (for images and web pages etc). The amount of non-volatile storage space is determined by the choice of operating system, but for practical purposes a limit of four megabytes was set. The previous Netslate project had one megabyte of storage space. Several different options for non-volatile storage, including EPROMs, Flash EPROMs and small hard drives were investigated. Of these options, the Flash EPROMs won on all counts – size, cost, speed, ease of use and availability. Four megabytes of high performance flash memory was chosen, occupying a space roughly one quarter of the previous generation Netslate's program flash memory board space.

The volatile temporary storage space is needed since non-volatile memory is not suitable for the frequent modification that a modern operating system implies. In addition to this, volatile memory is significantly cheaper and faster than non-volatile memory, so by adding some form of volatile memory to the system, larger programs and web pages can be viewed, and at higher speed. There are only two basic forms of volatile memory in common use – Static RAM (SRAM) and Dynamic RAM (DRAM). Static RAM is faster, smaller, more expensive and more power hungry than DRAM. Although SRAM is faster than DRAM, DRAM is more appropriate because it is cheaper, still faster than Flash EPROM, and more available. After reviewing the DRAM market, it was decided to use a common DRAM module rather than buying individual memory chips – this allows easy upgrading in the future, and DRAM modules are more widely available than DRAM chips, as there are several different standard DRAM module types on the market, most of which are designed for PC motherboards. These modules were reviewed in terms of size, cost and availability. The most appropriate modules were in a format usually used in notebook computers – the so called “Small Outline Dual Inline Memory Module”, or SO-DIMM. Two of these modules were obtained, one 16MB module (donated by Micron Technologies [42]) and a 32MB low power module.

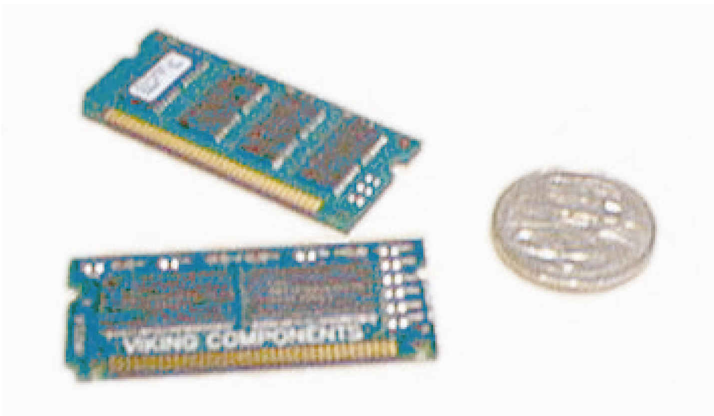

Figure 16 - SO-DIMM Memory Modules

In addition to these two memory banks in the TINA module, a facility was provided to allow for a ROM emulator to be attached via a daughterboard. This enabled rapid software development, and also provides a method for expansion in the future. The expansion daughterboard isolates the core circuitry of the TINA Motherboard from the ROM emulator, as well as translating voltage levels from the 3.3 volt StrongARM CPU to the 5 volt ROM emulator.

4.2.1.4 Communications

The vision of the TINA project was to have a completely wireless, hand-held web browser. To achieve wireless use, a "base station" that connects to the wired network is necessary, whether this be part of the TINA project or a cellular phone base station. The hardest task to achieve this goal is that of communications – how does the browser obtain the data from the Internet in the first place? In previous years, this problem was solved by using Infra Red technology. This approach had several serious defects – the handheld web browser was limited to a range of a few metres around the Infra Red base station. For the new TINA Project communications system, the following criteria were considered:

- Range – How far can the user roam?
- Speed – How fast can data be transferred?
- Cost and Availability
- Ease of Use – is detailed communications engineering knowledge required?
- Compliance with applicable Australian regulations

There are only two basic technologies that can be used to transfer data wirelessly: Infra Red and Radio Frequency. Infra Red hardware is fairly cheap, but still fast, but is usually limited to line-of-sight communications. This places a severe restriction on the distance the user can roam away from a base station. Radio Frequency (or RF) communications are used extensively to overcome the line of sight problem, most notably with mobile (cellular) phones. RF communications can penetrate concrete, allowing greater freedom of movement. Several ranges are available, from very slow, very tiny modules intended for data logging, to extremely fast modules designed for wireless networking, operating in the tens of megabits per second range.

Several different products that offered reasonably fast communications were investigated: Linx Technologies HP Data Transceiver Modules [38,37], Radiometrix BIM Wireless Data Transceivers [50], and the Harris Semiconductor PRISM Chipset PCMCIA Transceiver [19], as well as a selection of other wireless networking products. However, most of these were unsuitable because they were either very expensive or required the user to have detailed RF analog design skills. The following table displays some of the products reviewed.

Criteria	Linx	Radiometrix	Prism
Range	400m	120m	1200m
Speed	50kbits/s	40kbits/s	Up to 2Mbits/s
Cost	$100	$80	Over $300
Availability	Poor	Good	Poor
Ease of use	Good	Good	Good
Skill Required	Low	Low	High
Regulation Compliance	Good	Good	Good

Table 6 - Comparison of RF modules

Despite the reduced cost and increased availability of the Radiometrix modules, the Linx Technology modules were chosen. These modules offer speeds of up to 50 kilobits per second (as fast as modern telephone line modems) over 400m, in a completely integrated package at a reasonable price. Figure 17 shows a picture of the Linx modules employed in the TINA Project, with a twenty cent coin to show the scale.

Figure 17 - Linx Technologies HP Data Transmitter and Receiver Modules

The transceivers were also compliant with Australian spectrum management regulations. After the order was placed in March, the supplier decided to redesign their product range, delaying the receipt of the modules to September – an extremely frustrating state of affairs, especially given the time constraints, but one encountered often in Australia.

4.2.1.5 Peripherals

One of the key features of the TINA vision is convenience. To this end, the TINA device needs to support a variety of peripherals. Several different input methods were considered, including touch screens, touch pads, keyboards, mice, track balls and joystick-like devices. One requirement of the input device is that it be usable when the TINA device is being carried around. Because of the need for convenience, a touch screen was chosen. Touch screens are considered to be one of the most convenient and intuitive form of input. In addition to the primary touch screen input device, a keyboard and perhaps an external mouse would be convenient, so support for PS/2 mice and keyboards [49] was added to allow the user to type in Web page addresses easily.

In addition to these input devices, a high speed serial port that can be connected to a modem to enable remote access away from the wireless base station or used as a debugging console was considered necessary.

To achieve these features, most of the peripheral control is performed by a separate on-board micro controller, allowing the main CPU to concentrate on the operating system and Internet applications. The two CPUs communicate over a high speed serial link (1MHz Motorola SPI protocol), allowing rapid exchange of information when needed.

4.2.1.6 Power Supply and Battery Charger

In order to support the fully portable vision of the TINA Project, one of the more critical modules of the project was the power supply. Since the TINA project was envisaged to be a totally portable, wireless WWW Browser, it is necessary to have a power supply that will operate off a battery pack or some other source of portable energy. A few technical possibilities were investigated (a good summary can be found in [9]), including Nickel Cadmium (NiCad) batteries, Nickel Metal Hydride (NiMH) and Lithium Ion (LiIon). A Nickel Metal Hydride battery pack was deemed suitable for the TINA project on the basis of cost, capacity, weight and size. To complement this battery pack, battery charger circuitry was used so that the batteries could be recharged when the TINA device was powered from an external power supply. Figure 18 illustrates the design of the power supply module.

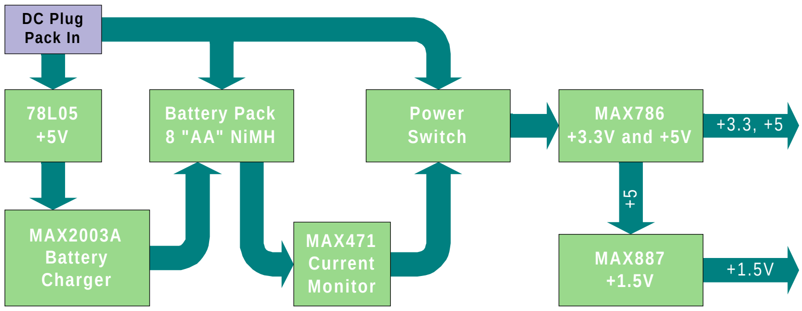

Figure 18 - TINA Power Supply Block Diagram

In order to maximise battery life, switch mode buck converters (switch down) are necessary to produce efficient voltage supplies for the motherboard's requirements. In addition to these features, the capability to monitor battery current and voltage was added, to ensure that the main CPU could show the user the estimated battery capacity.

Figure 18 also shows the optional DC Plug Pack that allows the batteries to be recharged. The TINA Project can run off batteries, but when these are depleted, the TINA Project must be connected to an external power supply. This power supply needs to supply approximately 18 volts at around 1 Amp. The design of this power supply was simple, using off-the-shelf components. The finished module is presented in Section 4.2.2.1.

4.2.2 Physical Construction

The construction of the TINA module involved the design and construction of several printed circuit boards, and the design and production of a suitable case for the TINA module. There were four circuit boards produced for the TINA module – an external power supply, the internal power module, an expansion daughterboard, and finally the TINA Motherboard. A case, described in Section 4.2.2.5, was built out of clear acrylic to house the TINA module.

4.2.2.1 External Power Supply

This module, described in Section 4.2.1.6, converts a 16V AC input to an 18V DC output. The finished two layer circuit board (2.4x1.5 inches) was placed in a small box to prevent electrical shorts, shown in Figure 19. There were no significant problems encountered in the construction of the power supply.

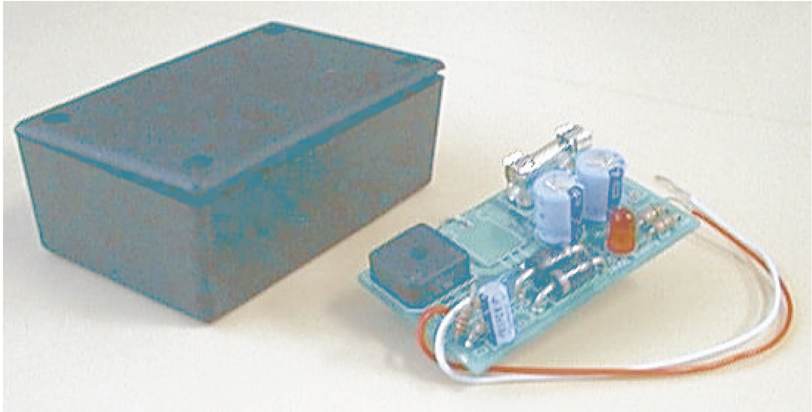

Figure 19 – Finished External Power Supply Module

4.2.2.2 Internal Power Module

The internal power supply, described in Section 4.2.1.6, operates off the battery pack. This PCB is one of the more dense circuit boards produced for the TINA Project, integrating 90 components in a two layer circuit board 2.7 by 4.6 inches, as the assembled module in Figure 20 (shown with battery pack) shows. There were no significant problems in constructing this circuit board, and the final module is a sophisticated power supply that performed above expectations.

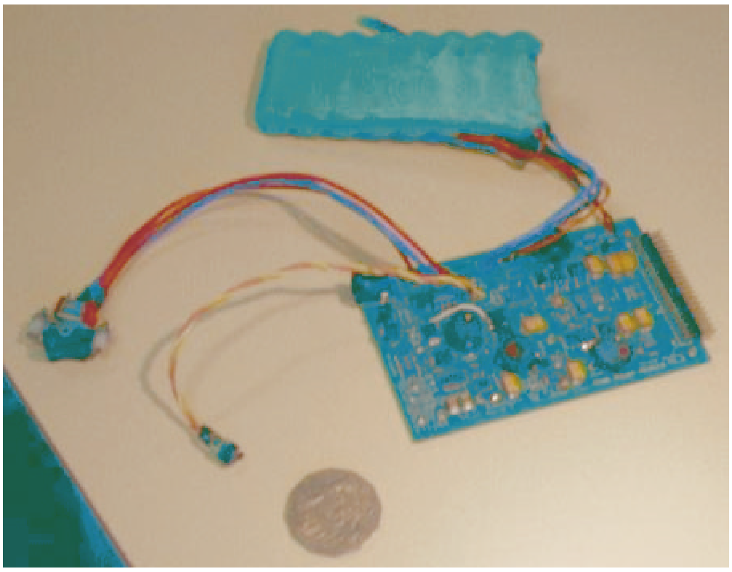

Figure 20 - Internal Power Module PCB

4.2.2.3 Expansion Daughterboard

The expansion daughterboard (Section 4.2.1.3) allows the TINA module to be connected to external devices like a ROM emulator. The two layer circuit board designed squeezes two ROM sockets and several buffer chips into a small board (1.8 by 4.7 inches). Once constructed (Figure 21), several intermittent problems plagued the use of the module, finally being traced down to the soldering of the surface mount connector. Once this connector was resoldered, the expansion daughterboard allowed rapid software development.

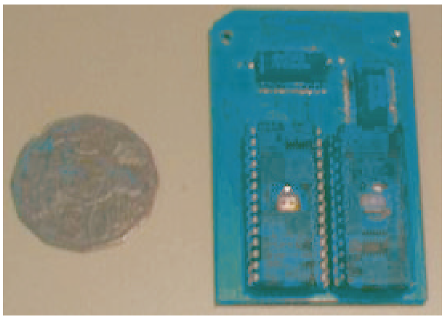

Figure 21 – Constructed Expansion Daughterboard Module

4.2.2.4 TINA Motherboard

The TINA Motherboard integrates all the modules from Section 4.2.1 except the power supply. It contains the 200MHz StrongARM CPU, both types of memory, and all of the peripheral hardware. Commercial designs with this type and speed of circuitry are usually four layers at the minimum [32], with six or eight layers being used for especially high quality designs. Unfortunately due to the budget for this project, a two layer circuit board was the limit. Despite this critical handicap, a fully functional two layer circuit board was designed – one of the greatest achievements of the TINA Project. Figure 22 shows the completed TINA Motherboard with all of the other TINA Module circuit boards attached. Several problems with soldering quality and mechanical stress were encountered during construction of the TINA Motherboard, which were eventually rectified. This was not really unexpected, since the chips employed in the motherboard design were extremely fine pitched, with the smallest pitch belonging to the StrongARM, which has 208 pins with roughly 0.2mm of free space between each pin.

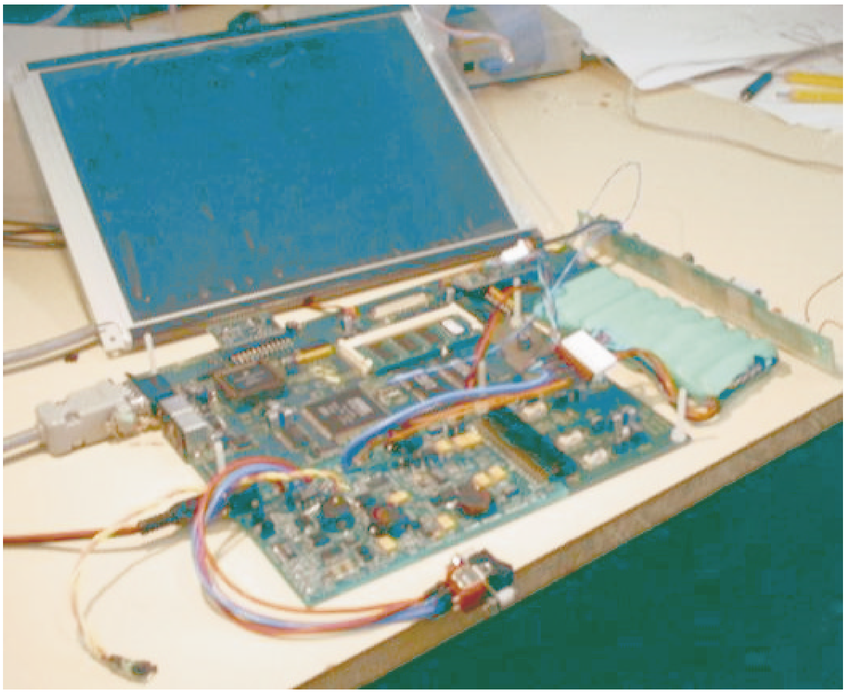

Figure 22 - Completed TINA Module, without case

4.2.2.5 TINA Case

The TINA module required a case to house the many circuit boards. This case was designed to be more comfortable than a simple box, but due to a lack of time and mechanical skill, the case design was reduced to a simple box. Appendix A shows the original design of the TINA Module case. At the time of writing, the final case had not been constructed.

4.2.3 Software Modules

Of course, the best hardware will not be useful without software. The TINA Project has a considerable amount of software, from the low level BIOS (Basic Input Output System), device drivers and operating system kernel (the core functions) to the user applications like the web browser and E-Mail client. Several options were evaluated for each of these software modules as described below.

4.2.3.1 Low Level BIOS

The BIOS for the TINA module is responsible for managing the low level operation of the TINA hardware. This software is often called "firmware", since it resides at the boundary of software and hardware. There are two separate firmware modules, one for each CPU on the board. The peripheral controller, a Motorola 68HC11E2 [44], is responsible for decoding the PS/2 Keyboard and Mice [49] ports, as well as measuring battery voltage and current. The peripheral controller firmware is also responsible for reading the touch screen.

The StrongARM SA1100 firmware is a lot more complicated. This software, called the Debug Command Interface [61], or DCI, allows the user to access low level hardware by typing commands via the serial port. The DCI is responsible for configuring all of the TINA module hardware such as the CPU, DRAM and wireless data link. The DCI also contains the Inferno kernel, described in Section 4.2.3.2.

4.2.3.2 Operating System

The operating system is the most important portion of the software for the TINA Project. The choice of operating system directly determines the difficulty of realising the TINA Project aims, since a good choice of operating system will reduce the amount of work required to implement the rest of the software. The following requirements for an operating system were determined:

- Support for the TINA Hardware (CPU, storage space, display etc)
- Support for a Graphical User Interface (GUI)
- Support for secure network protocols
- Sophisticated software support (multiple processes etc)
- Implementation not overly complicated or difficult (due to time constraints)

The first choice made was whether to use an existing operating system or to write one from the beginning. The work involved with writing an operating system capable of running a web browser, an E-Mail client and other applications at the same time as managing peripherals and network access is significant – it was decided that writing an operating system especially for TINA was impractical. This workload also meant that an operating system that included a web browser and an E-Mail client would be preferable over one that required all applications to be written. This limits the choice of operating systems significantly – only two operating systems could be seriously considered: Lucent Technologies' Inferno [40], and the Linux Operating System [36]. The previous Netslate 97 [47] project used the Inferno O.S., so some prior experience with the O.S. had been obtained. The two operating systems were reviewed on a number of criteria (in order of importance):

- Support for TINA CPU (Digital StrongARM SA1100)
- Ease of porting to the TINA architecture
- Support for desired applications (web browser, e-mail client)
- Size of Operating System
- Development Environment
- Cost

Criteria	Inferno	Linux
CPU Support	Yes – built in	Yes – not built in
Ease of Porting	Easy	Moderate
Application Support	Yes	Yes – extensive
Size	Small	Medium
Development Environment	Adequate	Good
Cost	Donation	Free

Table 7 - Comparison of Operating System choices

Both Operating Systems would support the TINA hardware. It was felt, however, that the work involved with getting Linux running on the TINA hardware would be more than that required for Inferno. Both O.S.'s support web browsers and E-Mail clients (Linux better than Inferno), but the storage space required for the Linux applications is much larger than the Inferno equivalents. Both O.S.'s have good development environments – there is a Windows 95 Inferno emulator, which allows development of Inferno applications easily, and there are many good Linux development systems. Linux has the better development environment, simply because Linux is a much more common OS than Inferno. Finally, both operating systems would be essentially free – Linux because that is the way it is licensed, and Inferno because the University of Queensland is an "Inferno Champion", which means that Lucent gives the Inferno material to the University to foster Inferno development.

It was concluded that Inferno was the more suitable operating system for the TINA Project, as it was more suitable for Internet Appliances, in addition to having a smaller "footprint" (the size of the O.S.). Inferno is rapidly becoming a serious contender in the Network Operating Systems market, with companies like Microsoft and Sun considering it a serious competitor.

4.2.3.3 Web Browser

Having made the choice of the Inferno OS, several software design issues become easier. Inferno comes with a rudimentary web browser as standard. A screen shot of the web browser running under Windows 95 is presented in Figure 23.

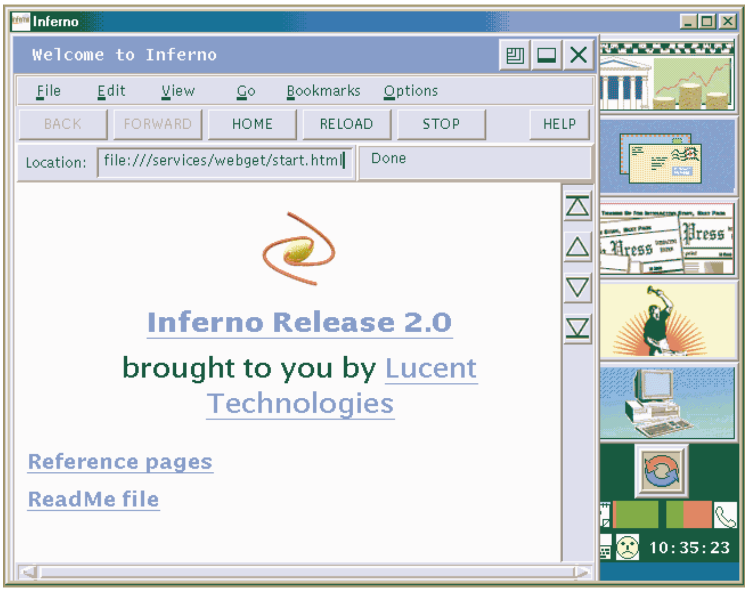

Figure 23 - Screen Shot of Inferno Web Browser

This browser does not support all of the recent HTML improvements such as frames or scripting languages, but still supports basic HTML functionality. The lack of frames is perhaps the most serious shortfall, as many web pages employ multiple frames. This limits the real world usability of this browser. This gave rise to a decision – either write a new web browser from scratch, or use the existing browser, possibly upgrading it. These options were assessed according to the following criteria:

- Work load
- Complexity of task
- Quality of end product

These three options were assessed as follows:

Criteria	Old Browser	Upgraded Browser	New Browser
Work Load	Light	Medium	Very High
Complexity	Light	Medium	Very Complex
Quality	Low	Medium	Good

Table 8 - Comparison of Web Browser choices

From this table, if all criteria were given equal weightings, the best choice would be the old browser. The option of writing a completely new web browser is an extremely time intensive option, and it was felt that the benefits did not outweigh the costs. The upgraded browser, on the other hand, was still considered a viable option. The web browser used in the TINA Project is a slightly improved version of the standard Inferno browser – unfortunately time limits prevented further development.

4.2.3.4 E-Mail Client

Along with the World Wide Web, e-mail is one of the most important Internet applications. As such, the TINA Project requires an e-mail reader. It is possible to send e-mail using the TINA Project device, but without a keyboard built in, this is more of a chore. The Inferno distribution also includes an e-mail reader. Figure 24 shows a screenshot of the original Inferno e-mail client.

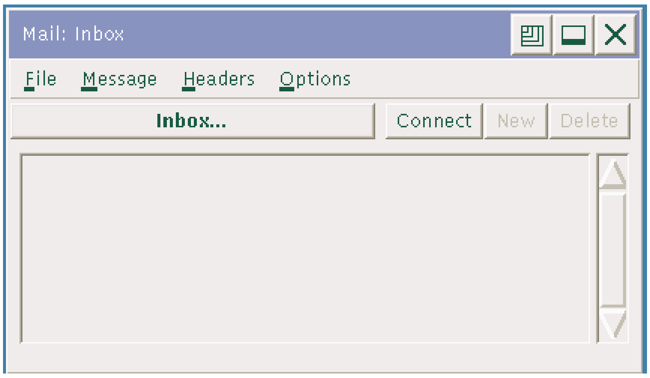

Figure 24 - Inferno E-mail Client

The Inferno e-mail client is not the most sophisticated, but it provides basic e-mail functionality for the TINA Project. At the time of writing, this program was not improved significantly. Planned features for the e-mail client included an interface rework, an address book and support for multiple e-mail accounts. These features would make the TINA Project e-mail client a lot more useful.

4.2.3.5 Other Applications

There are several other applications that can be run on the TINA Project – games, Usenet News readers, even information browsing tools like electronic books can be implemented. Inferno comes with several other applications, including a movie player, a text editor and several demonstrations. Several applications were written for the TINA Project, including a new user interface that is more suited to touch screen use (shown in Figure 25), a "virtual keyboard" application that displays a keyboard on the screen to allow the user to touch the screen to type in web addresses, and a port of a graphical demo of a rotating hypercube [15]. These applications were written in "Limbo" [39], the programming language of Inferno.

Figure 25 - New User Interface for the TINA Project

4.3 Base Station Implementation – the NINA Module

Unlike the complex TINA module, the NINA module is very simple. The following diagram (Figure 26) illustrates the structure of the NINA module.

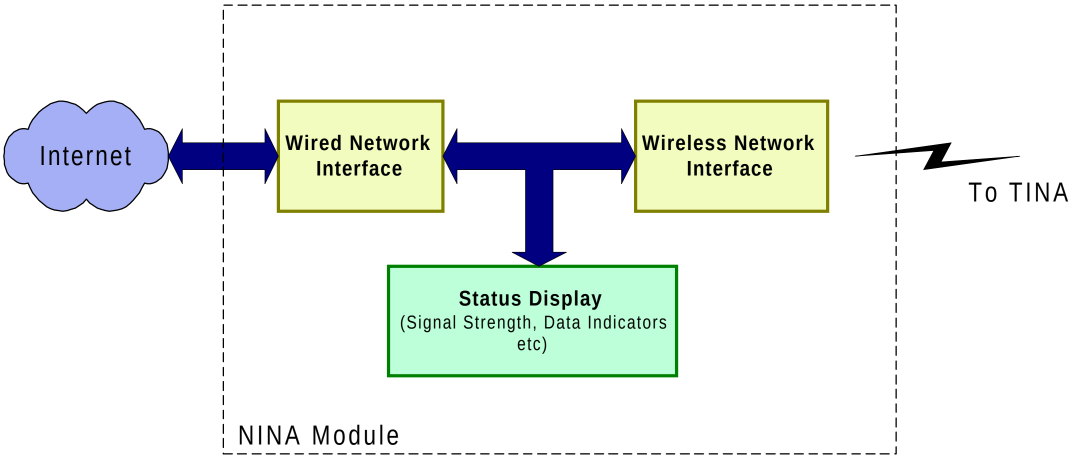

Figure 26 - Block Diagram of NINA Module

From Figure 26 it is evident that there are three main parts of the NINA module: the Wireless Data modules, the Wired Data module, and finally the Status module. Each of these sections is discussed in greater detail below. Following the description of these modules, the physical design of the NINA module is presented.

4.3.1 Wireless Data

Since the NINA module is intended to support the TINA device, the choice of wireless data transceivers should be the same as that used in the TINA device. For this reason, the Linx Technologies HP data transceivers were chosen for the reasons discussed in Section 4.2.1.4.

4.3.2 Wired Data

The other communications problem is the wired end of the base station. This is necessary to actually provide information to the TINA device. There were several types of wired networks to choose from, varying in terms of speed, complexity and cost. Network types that were investigated included Ethernet, RS-232 Serial links, IrDA and customised ISA bus hardware. These network types were assessed on the following criteria:

- Cost
- Network Protocol
- Complexity of Interfacing to Network
- Speed of Network

- Common use of the Network

The following table summarises how the previous networks were assessed in terms of these criteria.

Criteria	Ethernet	RS-232	IrDA	Custom ISA Card
Cost	Medium	Cheap	Medium	Medium
Protocol	TCP/IP	PPP	IrDA	Custom
Complexity	Medium	Simple	Medium	Complex
Speed	Very Fast (10+ Mbps)	Fast (115 Kbps)	Fast (115 Kbps)	Very Fast (8+ Mbps)
Commonness	Common in offices, uncommon in homes	Extremely common	Uncommon	Very rare

Table 9 - Comparison of Base Station Wired Network Types

Another factor that must be taken into account when choosing a wired network type is the maximum speed of the wireless data transceiver modules chosen – 50 kilobits per second. This means that any of the previous network types could be used based on speed. With this in mind, the RS-232 option was chosen to simplify the circuit design. This choice means that the Base Station will be connected to a computer with an RS-232 serial port (just about every PC built in the last twenty years has a serial port or two), and that computer will either contain the web pages to view, or will have a connection to the Internet at large. Another reason for using RS-232 as a network type is that the Linx Technologies wireless data modules support RS-232 nearly directly. This simplifies the circuit design considerably.

4.3.3 Status Module

The final part of the NINA module is the Status module. This module provides the user with information on the state of the wireless data link, with an indication of signal strength, as well as indications of data transmission and reception. These indicators are essential to verify the operation of the network link, and are simple to implement.

4.3.4 NINA Module Physical Construction

The NINA Module was very simple to implement, as most of the complexity in the design is contained in the Linx Technologies' RF modules. Figure 27 shows the constructed circuit board. The finished module was fitted into a normal instrument case, shown in Figure 28, with suitable panels cut out for the connectors and indicators.

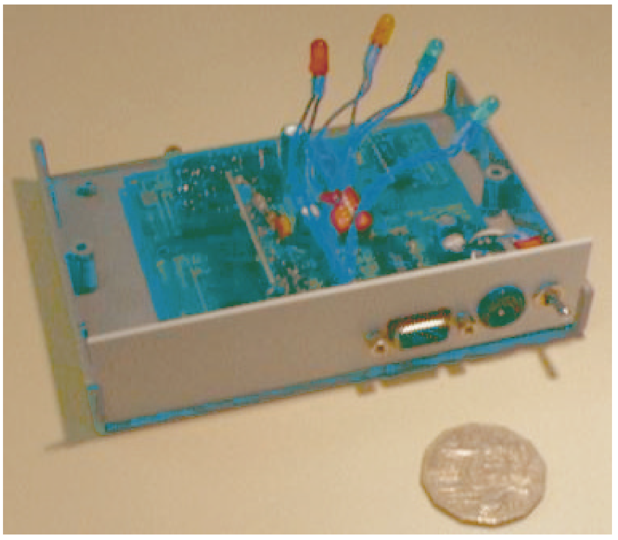

Figure 27 - NINA Module Circuitry

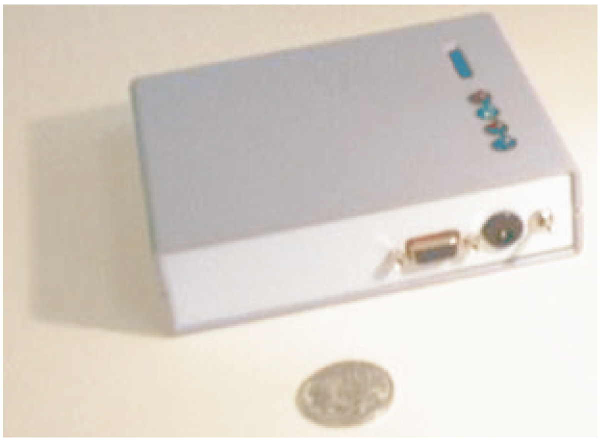

Figure 28 - Finished NINA Module

5 Results

5.1 Summary of TINA Project

At the time of writing of this report, most of the TINA Project was complete. Basic functionality was achieved, but full functionality has been hampered by intermittent technical problems. Despite this, the demonstration of the TINA Project is projected to proceed according to plan. Details of the performance of the TINA and NINA modules are presented separately.

5.1.1 TINA Portable Web Browser Module

At the time of writing, the operation of the TINA module is not totally successful. Due to a number of unplanned for delays in obtaining several key hardware components, design of the TINA motherboard was delayed by two months, causing the project to fall behind schedule. Once all the hardware modules were constructed, several problems were discovered:

- Lack of solder on some joints caused bad signals
- Several signals showed poor waveforms due to the two layer PCB design
- Mechanical stress caused bad joints
- Sensitivity to electromagnetic noise and interference

After the soldering and mechanical problems were fixed, the problems remaining were not easily solvable These problems were caused in part by the lack of a good ground plane [28,32] due to the necessity of a two layer design. The poor signal response caused a number of timing problems, limiting the maximum safe operating speed of the CPU. These signals were improved by terminating the poor quality traces correctly, but high speed operation was still prevented. The susceptibility of the motherboard to electromagnetic interference probably requires a PCB redesign to solve, but the addition of a shielded case would help considerably.

At the time of writing, the TINA module hardware was operating reliably. All components worked, including the wireless data modules, the DRAM, the Flash

EPROM and the Peripheral Controller. The TINA module is fully portable, being able to run off an internal battery pack and use the wireless data transceivers. The LCD controller works satisfactorily, although an intermittent connection to the LCD prevents proper consistent operation. The firmware works correctly, providing low level access to the TINA module hardware, allowing the battery statistics to be monitored, keystrokes to be received and the touch screen to be decoded into coordinates, as well as memory management and other kernel functions.

The port of the Inferno OS was also rescheduled due to a delay in the licensing for the latest version of Inferno. This delay did not prevent the development of the Limbo applications described in Section 4.2.3.5, but did prevent the Inferno device drivers from being written by the time this report was created. Since the device drivers will simply call firmware code already written and tested, it is expected that a full demonstration of the TINA Project will be possible by thesis demonstration day.

5.1.2 NINA Wireless Base Station Module

The NINA Base Station functions correctly when tested with the Linx Technologies evaluation kit and the TINA module. The indicator LEDs show when data is being transmitted and received, as well as when an RF carrier is detected. A bar graph LED display indicates the relative signal strength. In summary, the NINA Module worked as designed.

5.2 Comparison with specifications

In order to assess how successful the TINA Project was, a comparison with the specifications derived in Section 2 is necessary. As the TINA module is not one hundred percent operational, parts of this comparison have been performed using the Inferno emulator developed for Windows 95 as the majority of the software will remain the same for the final demonstration. The achievements of the TINA Project in the three major features, ubiquity, convenience and security are reviewed, followed by a summary of the performance of the TINA Project as a whole at the time of writing.

5.2.1 Ubiquity

The majority of the specifications for ubiquity are well satisfied. Table 10 shows a summary of the performance of the TINA Project for performance. There are two areas where the TINA Project did not exceed expectations – the cost, and the robustness. Since the TINA Project is a prototype, the costs for manufacturing would be significantly less than the cost involved with building the product prototype. At the time of writing, the TINA module lacked a case, which considerably limits the robustness of the design. The two devices produced (the wireless base station and the portable web browser) form a solution that could well become ubiquitous with a little more development.

Specification	Performance
Wireless	Fully wireless, with internal power supply
Portable	Fully portable, self contained
Hand Held	Fully Hand Held, with fixed base station
Cheap	Cheap relative to a notebook, with the projected price of manufacture less than $1000
Robust	Some sensitivity to electromagnetic interference, no case at the time of writing

Table 10 - Summary of TINA Project Performance (Ubiquity)

5.2.2 Convenience

The most important set of specifications, that for convenience, is addressed well by the TINA Project, especially considering the budget of the project. The only detractions from the convenience of the TINA Project are the case and the battery life. In a commercial environment, these problems could be resolved more easily, with either additional funds or specialised equipment. At the time of writing, the case designed for the TINA Project had not been constructed, but the case design would benefit from proper industrial design and injection moulding techniques. The battery pack for the TINA Project was created from consumer rechargeable batteries, so access to notebook battery technology would improve battery life significantly. Table 11 summarises the performance of the TINA Project in terms of convenience.

Specification	Performance
Light weight	Fairly light, weighing around one kilogram
Comfortable	Rounded case design should be somewhat comfortable, although a professional case would provide much more comfort
Good Display	The 10.4" display is quite large, but picture quality is merely adequate
Instant On	The device is ready for input within 2 seconds of being turned on
Intuitive	The touch screen provides an intuitive input method, and the use of a single button (used for power) eliminates confusing button arrays.
Compatibility	The Inferno OS allows any Inferno application to be run on the TINA Project, but there are not very many Inferno applications at the time of writing. The other TINA applications, including the e-mail client and web browser, are compatible with recent standards, although the web browser does not implement all of the most recent HTML standard.
Long Battery Life	The battery pack used in the TINA Project provides around an hour of portable use. This is not particularly convenient, so an improved battery pack is a necessity. This would be easier to achieve in a commercial environment.

Table 11 - Summary of TINA Project Performance (Convenience)

5.2.3 Security

The security specifications of the TINA Project were unfortunately the least well satisfied, with only one specification met. The TINA Project has built in user authentication, so unauthorised users are disallowed. The other security specifications, radio traffic encryption and support for secure web transactions, were not met due to lack of time. A problem with encrypting radio traffic is that the normal computers attached to the NINA Base Station do not support encryption, thus requiring extensive custom software to be written in the time constraints of a thesis project. Table 12 summarises the performance of the TINA Project with respect to security.

Specification	Performance
Encrypt radio traffic	The TINA Project is capable of encrypting radio traffic, but does not do so at the moment
Support secure transactions	The TINA Project is capable of supporting secure transactions, but does not do so at the moment
Authentication	The TINA Project supports user authentication

Table 12 - Summary of TINA Project Performance (Security)

5.2.4 Summary of Performance

The TINA Project fulfilled most of the specifications developed in Section 2. Additional development time would allow all of the specifications to be met, and it is projected that most of these shortfalls will be rectified by thesis demonstration day. The most serious fault is the lack of a case, and at the time of writing the case was being built by the UQ CSEE Mechanical Workshop. The Inferno device drivers are simple to write, and the Inferno port is projected to be completed before demonstration day.

Despite these problems, the TINA Project can be considered a success, since the potential for a portable web browser has been clearly demonstrated, with only a small amount of further development needed to complete the project.

6 The Future of the TINA Project

The TINA project has several areas for customisation or further development. These possible areas for improvements are discussed below. A summary of the most likely paths for further work is presented at the end of this section.

6.1 Display

The display used for the TINA project, while perfectly adequate, is somewhat behind the state of the art. An active matrix LCD screen would improve the picture display measurably. The fitting of a new screen to the TINA project is mainly a matter of funding, since the TINA project can handle both active matrix and passive matrix types with relative ease. This direction of improvement is not seen to be critical as the current solution is satisfactory.

6.2 Battery and Power Supply

The TINA Project relies heavily on a portable power supply, and this is one of the major limitations of the TINA project. In order to be competitive with recent notebooks, an extended battery life is needed, but unfortunately the current power supply is rather limited in this regard. This aspect of the project could be improved by redesigning the power supply to run off higher quality battery types like Lithium Ion cells. The prime difficulty with this development is the design of a suitable battery charger and battery protection system – Lithium Ion batteries in particular have a reputation of being explosive when used incorrectly. Once again, this would require only a rather small amount of further work.

6.3 Further Miniaturisation

One of the largest pressures on the electronic device market at the moment is that of miniaturisation. To this end, an attempt to compress the circuitry for the TINA project as much as possible was made, but given further development time an even smaller product could be created. With a smaller LCD screen, perhaps as small as the Libretto notebook, reviewed in Section 2.1.1, the TINA project could become even more portable. There is a delicate balance, however – too small and the screen is illegible, and the primary function of browsing the web becomes impossible. This is similar to the challenge facing electronic book developers.

6.4 Communications

One limitation of the current TINA project is the relatively slow network access speeds. These speeds are fully satisfactory for the home user, but intensive corporate users or multimedia heavy users might want faster access to the Internet. Several different varieties of wireless network access were researched, but most of these solutions were too expensive or too difficult to implement for students with no RF skills. Engineers with a more detailed understanding of RF design would be able to improve the network access speeds, resulting in a significantly improved product. With the growth of wireless networks like the Iridium [30] project, and the GlobalStar [17] network, true global wireless Internet connectivity is only a few years away.

6.5 Software

The software suite created for the TINA project was sufficient for thesis demonstration purposes, but for a fully commercially viable project the software should be improved. There are several areas of the software that can be upgraded – the most important of these is the web browser, since this is the primary focus of the TINA Project. Other possible applications of the TINA Project, such as process monitoring or on-line data entry, would also require new software to be developed. Several possible software upgrades are detailed below.

6.5.1 Web Browser

Since the main focus of the TINA project is on browsing the web, the web browser needs to be continually updated to meet the latest HTML specifications (and other emerging web technologies). The development of a web browser is a full time project in itself, so perhaps the easiest way to improve the web browser is to use a browser developed by a third party. The Web browser used in the current incarnation of the TINA project is sufficient for a lot of web pages, but the dynamic nature of the world wide web will necessitate an improved web browser.

6.5.2 Handwriting Recognition

A major area of possible expansion for the TINA project is handwriting recognition. The TINA project already boasts a touch screen, so it would be a matter of writing software which interprets the user's finger/stylus movements on the screen to produce usable text. This would be a very useful feature for the TINA project – it might be possible to create a standard "alphabet" for TINA similar to the Graffiti [1] system for the successful 3Com Palm Pilot series.

6.5.3 Process Monitoring

Another possible use of the TINA project is as an industrial process control remote terminal. Already companies like Honeywell [23] are using HTML technology to present a familiar interface to allow the user to control industrial processes. The TINA project could be used while out in the work area, allowing secure control of a process while the user is actually inspecting the site. Some hardware changes might be necessary to support this operation – in particular, some "ruggedising" of the TINA project hardware would be necessary.

6.5.4 Medical Uses

The use of a secure link to an on-line medical database would allow convenient patient management. Patients' measurements could be entered directly into the database using a TINA terminal. This would increase the efficiency of the medical personnel by allowing all relevant personnel access to the most recent information. In addition, identification of the patients may be confirmed by looking at a snapshot of a patient stored in the database. Coupled with an electronic locating system such as the Active Badge Network [13], the TINA Project could help locate patients and equipment. The TINA project already has a lot of the features that would be needed in such an environment – perhaps the greatest omission is the lack of handwriting recognition, as noted above.

6.6 Electronic Books

The TINA Project web browsing platform could easily be extended to function as an electronic book, as web pages are very similar in content to electronic books. These books could either be accessed over the Internet, with appropriate security measures to ensure copyright and distribution rules are met, or they could be stored in the internal memory of the TINA Project web browser. Given the wireless data transfer facility, the TINA Project would perhaps be more useful accessing the electronic books over the Internet. This would merely require a change in software, as the hardware platform is already suitable for electronic books, offering a large display and touch screen with a secure link to the Internet.

6.7 Commercial Potential

One likely avenue of development of the TINA Project is via commercialisation. Several companies expressed interest in the TINA Project as it was being developed because a working remote web browsing platform based on Lucent Technologies' Inferno would be an attractive package. Commercial development would include making most of the changes outlined in this section, and redesigning the circuit boards to meet governmental electromagnetic emission and susceptibility tests. This work is not feasible as a thesis project as the money involved is significant.

6.8 Future development of the TINA Project

There is certainly a future for the TINA project – this future may not be suitable for thesis students any longer, but there is always work to be done keeping the TINA project current. This work may be performed by commercial partners in the future, or as part of a larger project at UQ. Several technical areas of the project that can be improved have been outlined, and a discussion of the possible commercial future of the TINA project has been presented.

7 Conclusions

This thesis has presented an overview of the evolution of the TINA Project. The state of the TINA Project at the time of writing has been discussed, and while this is not complete, the TINA Project can still be considered a success within the limits of an undergraduate thesis. The breakthroughs and shortfalls of the TINA Project have been analysed, and it is hoped that the reader has gained an appreciation of the aims and achievements of this project, and that the future of the TINA Project has been presented in enough detail to allow further development.

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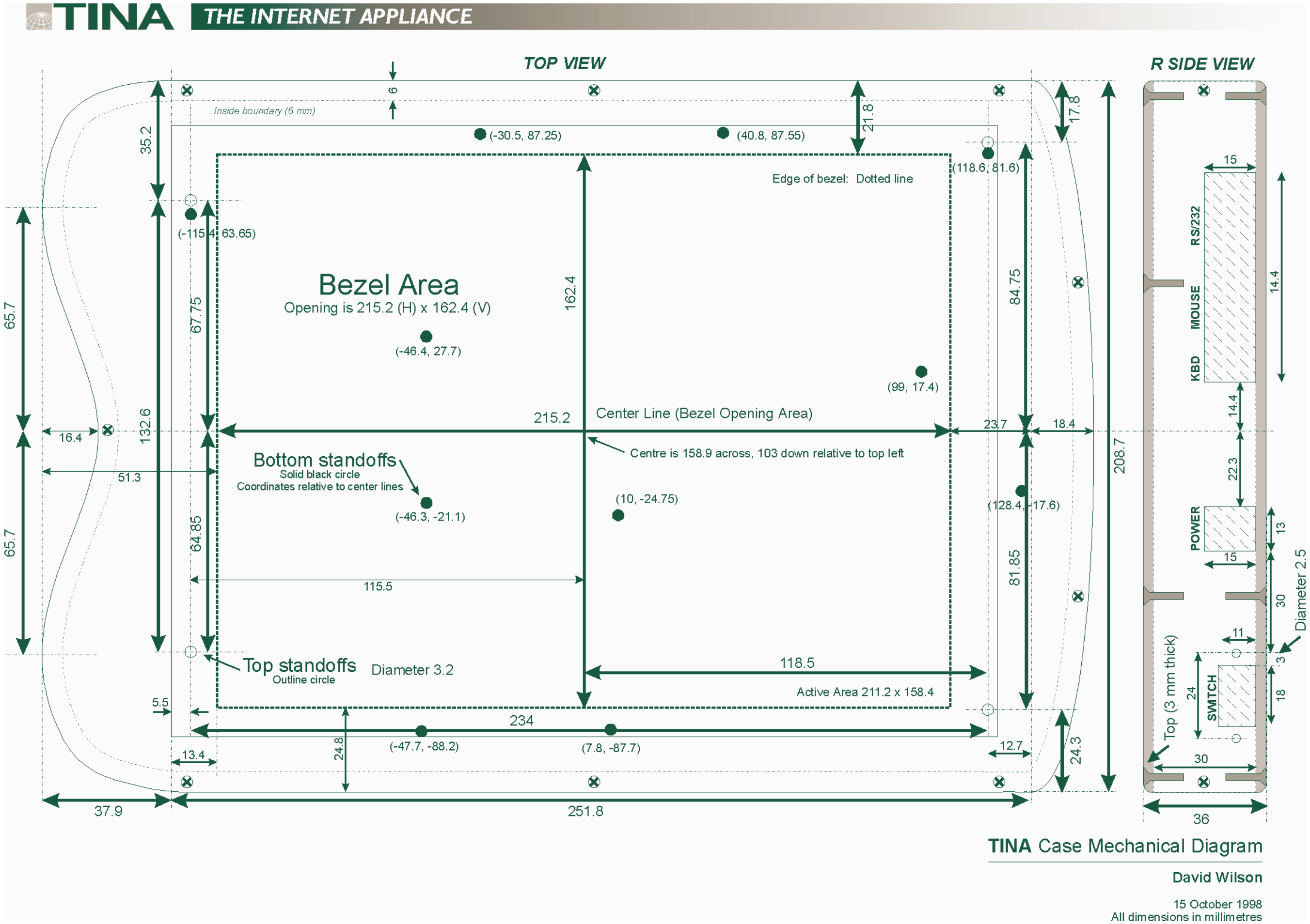
Appendix A – TINA Module Case Design



Appendix B – TINA Schematics

Due to Intellectual Property Disclosure rules, the TINA Project Schematics are not included within this document.

Appendix C – TINA PCB Artwork

Due to Intellectual Property Disclosure rules, the TINA Project PCB Artwork is not included within this document.