

Building products with NetBSD - thin-clients

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Who am I?

- Live and work in Cambridge, UK
- Managing Director of Precedence Technologies
- PhD in psychoacoustics (not Computer Science!)
- Citrix Certified Administrator (XenApp/XenServer)
- Citrix Certified Sales Professional
- NetBSD user since 1994
- NetBSD and pkgsrc developer/commmitter since Jan 2007

What is a thin-client?

- Small physical size
- No moving parts
- Low/medium performance
- Low power consumption
- Fast start time

What is a thin-client?

- No local storage (firmware only)
 - Small amount for local settings perhaps
- Centrally managed from network
 - Clients are commodity items that can be immediately swapped out if they fail
- Contains network client software, but no general applications
 - c.f. a fat-client which has whole OS and applications locally (e.g. MacOS, Windows), plus complex local configuration

Usual client software in thin-clients

- Citrix ICA
- Microsoft RDP
- X11
- Terminal (ssh/telnet/tn3270)
- Web browser
- VNC

NetBSD: first encounter

- Used Masscomp Unix and Irix as part of PhD
- Avid Acorn (ARM) user (at time)
- Wanted a Unix-alike to use and learn on
- Acorn RISCiX was 4.3BSD-based, but expensive, old and not for new machines
- RiscBSD project launched in 1994.
 - RiscBSD became NetBSD/arm32 and then NetBSD/acorn32

Relevant jobs

- **Feb 1996:** started at Acorn Education in tech support (part time – still doing PhD)
- **Apr 1996:** Acorn and Apple UK formed Xemplar Education.
 - Xemplar Education 2nd biggest supplier of IT to UK education. I transferred there full-time

Product history

- **Jan 1996:** Acorn launched Network Computer Reference Design with Oracle
- NC was 48MHz ARM7500FE, 16MB RAM, 10Mbit Ethernet, custom version of RISC OS, no local storage, boot from NFS, browser in ROM
- **Oct 1996:** Xemplar given 2 pre-release NCs by parent company Acorn. Sales/Marketing took one – I took other. I had a plan...

Product history

- Used NetBSD/arm32 on RiscPC server
 - Apache for web-based UI
 - Wrote web-based administration
 - Wrote webmail package
- Wrote/designed application framework
 - Not true thin-client as, except for web-based software, applications were running on client
- From summer 1997, solution sold to UK schools (NetBSD-based NCServer)
 - Means Apple were selling BSD Unix in 1997; a long time before Mac OS X.

The End?

- **Summer 1998:** Became Network Computer Technical Manager
- **Summer 1998:** Large roll-out throughout UK
- **Jan 1999:** Acorn sell 50% share to Apple, i.e. Xemplar were now 100% Apple
- **Mar 1999:** Most staff made redundant (inc. me)
 - Meant customers throughout UK with paid-up support contracts, but no support staff
- **Apr 1999:** Precedence starts trading. Buys NC stock. Contracted by Apple to provide support. Given all IPR and source code

A New Hope

- **Apr 1999:** Precedence sell CATS to replace aging RiscPCs (running NetBSD/cats)
- Re-position server as being a general purpose Internet/intranet/email/filtering server (NetManager)
- **Nov 1999:** Switch NetManager to NetBSD/i386
- **Apr 2002:** Start complete modular re-write (NG on NetBSD/i386 1.6.1)
- **Today:** NetManager NG 5 selling well (NetBSD/i386 5.0_STABLE)
 - Still do occasional NetManager builds for SGI (mips), PowerMac (macppc), HP Jornada (hpcsh), RiscPC (acorn32) as proof of concept

Baggage

- Still selling 48MHz clients, very proprietary
- Very slow, old RISCOS ICA client
- Evaluated netbooting NetBSD/acorn32 and running Linux/ARM ICA client – no benefit
- Refuse to sell Windows CE/XPe clients

Linux?

- Start to sell 233MHz+ Linux-based clients
 - Very poor support
 - Basic software
- Found alternative Linux-based clients
 - Slick UI
 - Pain to buy (have to import)
 - Expensive
 - No obvious future development plan

Brainwave

- Develop NetBSD-based solution to convert old PCs into thin-clients
- Chose name: ThinIT
- Started on 2nd May 2003. First release on 23rd May 2003 (v1.00)

ThinIT v1 outline

- Based on NetBSD 1.6 minimal install (base.tgz)
- Run from HDD with root mounted read-only
- Citrix ICA/Microsoft RDP clients only
- Use Linux emulation for Citrix ICA client
- Easy install (CDROM/floppy)

Brainwave v2

- Linux-based thin-clients expensive and few upgrades. No control over software.
- Why not use ThinIT on OEM hardware?
- Start from scratch to fix deficiencies of v1
- ThinIT v2.00 released Sep 05 for OEM hardware
- ThinIT v2.05 released for general PC: Sep 07
- ThinIT v2.08 in development (NetBSD 5.0-based)

Brainwave v2

- Search out low-cost, high performance clients
 - 1st generation TCX released Sep 05 (1GHz VIA-C3, 64MB flash, 128MB RAM)
 - 1st generation TCM released Jan 06 (1.5GHz laptop, 128MB flash, 256MB RAM)
 - 4th generation TCX released Sep 08 (1GHz VIA-C7, 128MB flash, 512MB RAM)
 - 4th generation TCM being built in Shanghai as I speak (12" widescreen laptop, 1.6GHz VIA-C7M, 1GB RAM, 128MB SSD)
 - Custom version for Asus EeePC

Product requirements (NetBSD)

- Needs to run from flash
- Easy build infrastructure
- Easy to test during development
- Should be able to boot from various sources (CDROM, USB, PXE, Flash, HDD)
- Should have slick consumer-facing user interface
 - No kernel text
 - No command line
 - GUI configuration
- Wide hardware support, but excellent performance on known hardware
- Needs to have small footprint (memory/storage)

Product requirements (General)

- Needs to be difficult to rip off or subvert
- Centrally configured
- Remote management
- Modular and extensible
- Many more session types
- Needs to run latest client software

How NetBSD meets requirements 1

- Run from flash
 - NetBSD installer has ffs image as root filesystem embedded in kernel with mdsetimage
 - Very easy to extend and build custom images
 - Requires small tweaks to boot multi-user as designed for single-user installation process
- Easy build infrastructure
 - build.sh can build whole system
 - Single make can do a lot
- Easy to test during development
 - Xen support good; generate filesystem image for Xen

How NetBSD meets requirements 2

- Boot from various sources
 - Very easy – just one file + bootloaders
 - Tweak pxebooters to hardwire TFTP path
 - bootxx_cd9660 means no more 2.88MB limit
 - boot.cfg allows boot menu for choice of kernels
 - e.g. run live from CD or run installer
 - Can still build floppies (though 3+ needed)
 - bootxx_fat16 allows USB booting w/o formatting)
 - NTFS boot (dual boot with Windows w/o partitioning)

How NetBSD meets requirements 3

- Slick user interface
 - Kernel boot messages must go
 - boot -z is NOT quite silent, but much better in NetBSD 5.0
 - Cheap hack – make printf do same as aprint_normal
 - Allow verbosity level to be compiled into the kernel so remains quiet with all bootloaders
 - Lock down boot loaders
 - Password protect, hardwire kernel path
 - Most of rc.d scripts rewritten
 - Differentiate between output to terminal (friendly text) and log to file (debugging)

How NetBSD meets requirements 4

- Slick user interface (continued)
 - Colour text, cursor positioning during text phase
 - Displays Ethernet link and wifi scanning status for example
 - vesafb/splashscreen
 - Friendly boot logo (optionally animated)
 - Unfortunately incompatible with ACPI suspend
 - Retired in -current in favour of genfb
 - GUI configuration (GTK)
 - Lots of pretty screen savers (xlockmore)

User interface at boot time



```
NetBSD MBR boot
NetBSD/i386 ffsv1 Primary Bootstrap

Precedence Technologies Ltd - ThinIT v2 (boot version:2)
=====
>> Memory: 638/260032 k
booting ThinIT (hd0a:thinit) - starting in 0
5744256+5494916+220116=0xae70c
Detecting hardware...█
```

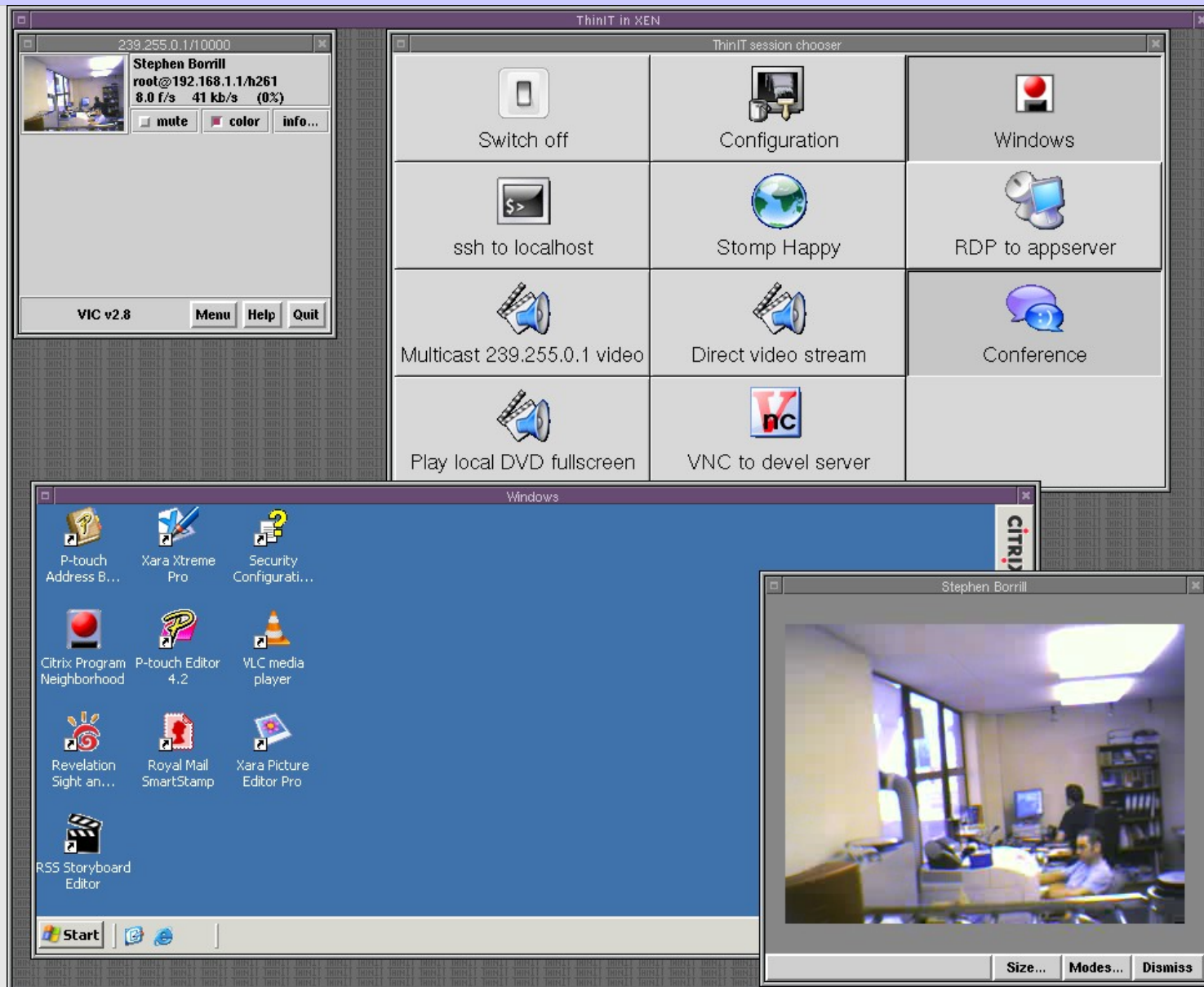
```
Booting ThinIT v2.05

Booting from local storage
Determining start-up options - Done
Looking for live network connections : 1
pcn0                                Wired
                                No cable
                                AMD PCnet-PCI Ethernet

Getting IP address via DHCP
My name: xnc112.precedence.co.uk   IP: 192.168.1.112   My ID: 000c290d24eb
Getting settings with TFTP from /thinit on 192.168.1.14
=> Client is in group standard
Checking for scheduled updates
Running version 2.05A - verifying - OK
Loading modules:
confer, emul, gui, ica, lib, opera, rdp, ssh, tk, video, vnc, x, xdrv
Launching...
```

- vesafb splashscreen (top left)
- non-vesafb version (bottom left)
- boot sequence (top right)

User interface when running



How NetBSD meets requirements 5

- Excellent performance on known hardware
 - Very cut down kernel configs for TCX and TCM clients and optimizations
 - Very quick boot times as no probing for unknown devices (fraction of a second after kernel loaded – took 10 seconds on ThinIT 2.05!)
 - Tweaked and updated X drivers

How NetBSD meets requirements 6

- Wide hardware support
 - GENERIC-type kernel for standard PC hardware
 - Unified self-optimizing kernel runs on a wide range of hardware
 - Many more drivers in NetBSD 5.0
 - New power-management framework in 5.0
 - Could easily switch to new processor/hardware
 - (though see caveats later)

How NetBSD meets requirements 7

- Small footprint
 - Crunchgen monolithic binary memory efficient
 - Kernel with embedded ramdisk (gzip -9 compressed)
 - Less than 3.5MB (for TCX)
 - Compressed vnd used for modules. Came along just at right time!
 - Severely pruned file list in modules (see later)
 - tmpfs efficient memory file system

Meeting general requirements 1

- Modular
 - ThinIT kernel is standalone. Knows how to upgrade itself, get settings, speak to various networks and find files on various filesystems
 - Supported by a number of modules which it loads either into RAM (over http/tftp/ftp or from CD) or from local filesystem (ffs, FAT, NTFS)

Meeting general requirements 2

- Modular (continued)
 - Modules are disk images created with makefs and configured as vnds (compressed + encrypted)
 - Some required (e.g. libs, X)
 - Some useful, but could be removed (e.g. gui)
 - Session modules optional (e.g. ica, rdp, vnc)
 - Some required by others (e.g. emul is required by ica)
 - Potential for custom development

Meeting general requirements 3

- ThinIT Makefile.vnd builds modules
 - Can use pre-built pkgsrc binary packages
 - Removes *.h, *.a, *.la & man pages by default
 - Supports extracting against a fixed list
 - Can include part of src tree (e.g. lib/libc)
 - Can build local sources (e.g. session chooser)
 - Can define extra stages (e.g. uncompress X fonts as they will be compressed later)
 - Builds ffs image, compresses and encrypts

Meeting general requirements 4

- More session types
 - Adding a new type as easy as adding a new module (based on pkgsrc binary packages)
 - Streamed video and DVD playback (vlc)
 - Web browser (opera)
 - Conferencing (mbone tools: vic, rat, wb)
 - ssh
 - vnc
 - Citrix ICA
 - Microsoft RDP
 - SIP
 - Datalogging
 - This variety of session types is unique in market

Meeting general requirements 5

- Difficult to rip off
 - Compressed modules encrypted
 - cgd tricky to use because must encrypt AFTER compression (ffs on vndz, vndz on ffs, ffs on cgd, cgd on vnd).
 - Extending vnd(4) to support decryption on-the-fly much easier
 - Check hardware we're running on
 - Check cpu, video, audio, wifi, Ethernet, etc.
 - Refuse to run if doesn't exactly match what is expected

Meeting general requirements 6

- Difficult to rip off
 - Encrypt/obfuscate embedded filesystem
 - Problem is that kernel and ramdisk are compressed, so same problem as above.
 - Signed modules (future)
 - Licence management
 - Subvert management protocol to count machines sharing licence numbers
 - Allow each client to monitor other clients on the network

Meeting general requirements 7

- Centrally configured and managed
 - Fetches config file with http, ftp or tftp
 - Path configured with DHCP option 151
 - Supports groups and per-machine overrides
 - Plain text format (DOS or UNIX line endings)
 - session.1.type=ica
 - session.1.name=Run Windows
 - session.1.server=icaserver
 - ica.usb=b
 - Shadow screen (x11vnc)
 - Can use ssh for problem solving
 - Documentation on website for using with Windows
DHCP/IIS

File sizes in ThinIT v2.08 vs 2.05

	v2.08	v2.05		v2.08	v2.05
rdp.enz	110,080	(101,376)	lib.enz	2,545,664	(2,016,256)
vnc.enz	123,904	(124,928)	xdrv.enz	2,002,432	(2,048,000)
xvia.enz	162,304	(135,680)	tcx.krn	3,510,604	(2,426,211)
xi810.enz	223,232	(207,872)	tcm.krn	3,787,473	(2,587,539)
xisis.enz	281,088	(225,792)	video.enz	4,649,472	(3,930,624)
ssh.enz	274,944	(261,632)	thinit.krn	5,638,161	(4,196,849)
confer.enz	420,864	(418,304)	emul.enz	6,132,224	(4,336,640)
tk.enz	1,228,288	(1,227,776)	x.enz	6,714,368	(5,730,303)
gui.enz	1,956,352	(1,301,504)	opera.enz	9,082,880	(8,435,712)
ica.enz	1,985,536	(1,886,720)	TOTAL	38,897,484	(32,333,666)

.krn files are kernels for different machines

Total includes only TCX kernel and TCX video driver (xvia)

2.05 based on 4.0_RC4 (Sep 2007). 2.08 based on 5.0_STABLE (May2009)

File size changes explained

- TCX kernel in v2.05 = 2,426,211 (4.0_RC4)
- TCX kernel in v2.08 = 3,510,604 (5.0_STABLE)
- Remember, this is kernel + ramdisk (gzipped)
- Raw kernel v2.05 → v2.08 **+16%** (~170k)
 - New 5.0 options: pseye(4), uvideo(4), PUFFS, etc.
 - Old options enabled: NTFS, ext2fs

File size changes explained

- Embedded ramdisk v2.05 → v2.08 **+65%(+800k)**
 - Crunched binary (+600k)
 - WPA (wpa_cli, wpa_supplicant) (150k)
 - Rest mostly due to library changes (e.g. proplib for ifconfig)
 - Other data (+200k)
 - WLAN HAL/firmware (ral, rum, ath, wpi, iwi, bwi)
- General increase in software size
 - Mainly Linux emulation and X libraries
- Need to bear in mind that early TCXs had only 64MB

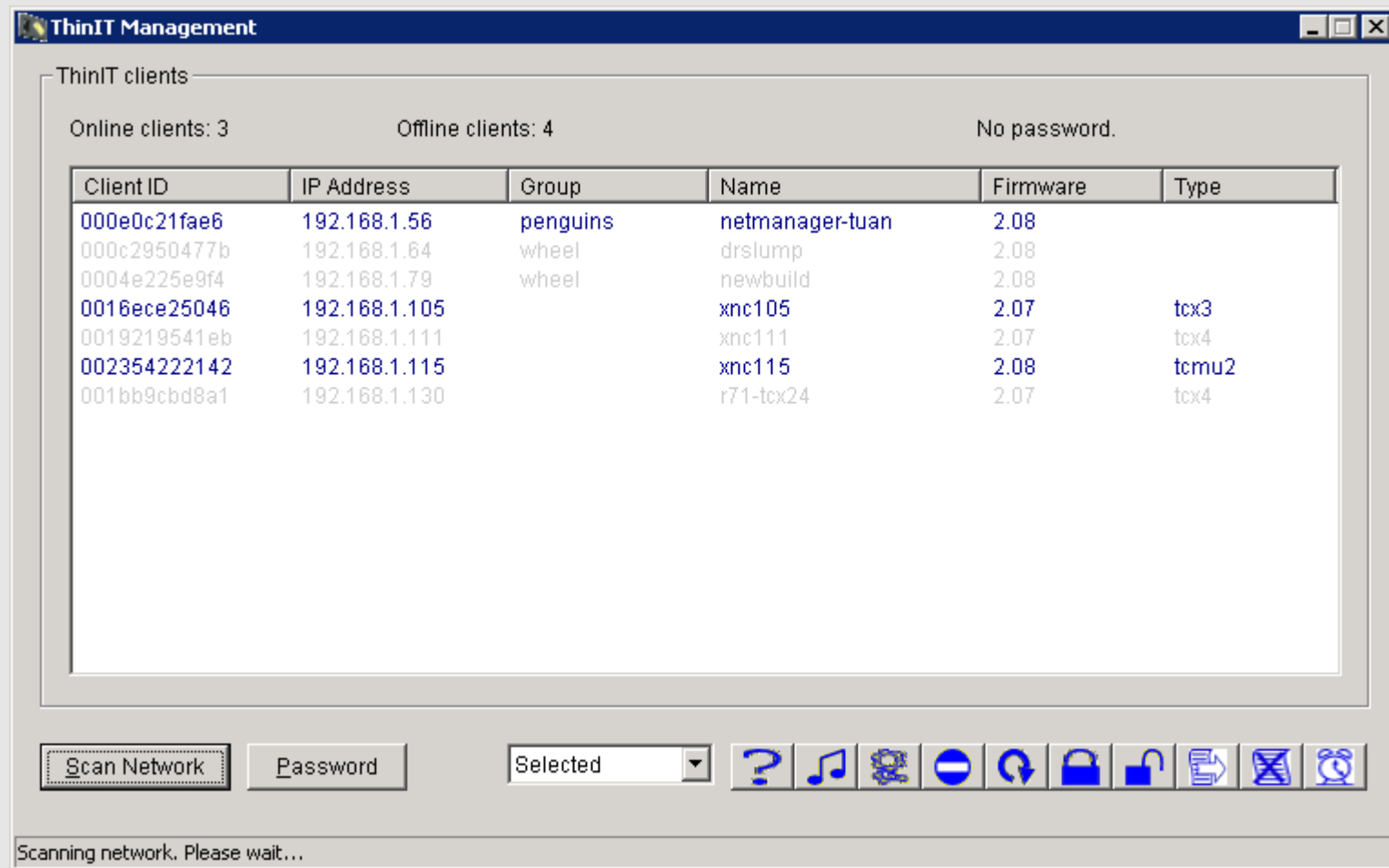
Client Management (BSD/Linux)

- Remote management with ThinITTool
 - Shutdown, reboot, probe, configure, view logs, start sessions, lock screen, play music(!)
 - NetBSD + Linux CLI binaries (no library dependencies)

```
NetBSD% thinittool -a PING
192.168.1.115 ACK:00000001 PING id=002354222142 group=r2 name=room2-1 fw=2.08 type=tcmu2
192.168.1.56 ACK:00000001 PING id=000e0c21fae6 group=r2 name=room2-2 fw=2.08 type=tcx3
192.168.1.110 ACK:00000001 PING id=0000dcc262fa group=r1 name=room1-2 fw=2.07 type=tcm1
NetBSD% thinittool -c 192.168.1.56 SHUTDOWN
NetBSD%
```

Client Management (Windows)

- Windows CLI + GUI binary
 - compiled on NetBSD with mingw



Client Management (web)

– Web-based frontend on NetManager

netmanager-tuan: Management (ThinIT management) - Mozilla Firefox

File Edit View History Bookmarks Tools Help

http://netmanager-tuan:880/private/services/thinit/index.php

Most Visited Getting Started Latest Headlines

NetManager
Administration System

Design by: Precedence Technologies Ltd
NetManager Admin Menu: v1.10/1.45/1.37

netmanager-tuan: ThinIT management

Logout
User Admin
Group Admin
E-Mail Admin
Web Proxy
Web Server
Filesystem
Printers
Network
Security
Services
Status
UPS
Jabber
Databases
ThinIT
System
Intranet
System Support

Summary

192.168.1.0/24 (main) Scan network

ThinIT Clients: 7 Online: 2 Offline: 5

Client ID	IP Address	Group	Name	Firmware	Type	Remove Selected	Password
000e0c21fae6	192.168.1.56	penguins	netmanager-tuan	2.08		☐	
000c2950477b	192.168.1.64	wheel	drslump	2.08		☐	OFF
0004e225e9f4	192.168.1.79	wheel	newbuild	2.08		☐	OFF
0016ece25046	192.168.1.105		xnc105	2.07	tcx3	☐	
0019219541eb	192.168.1.111		xnc111	2.07	tcx4	☐	OFF
002354222142	192.168.1.115		xnc115	2.08	tcru2	☐	OFF
001bb9cbd8a1	192.168.1.130		r71-tcx24	2.07	tcx4	☐	OFF

Selected

Key

- Ping
- Beep
- Reboot
- Shut Down
- Sessions
- Lock Display
- Unlock Display
- Get Setting
- Delete Setting
- Wake Up

Done

Problems hit against

- Few OEM laptop suppliers means pressure to use off-the-shelf laptops
 - Windows tax
 - HDDs redundant if replaced by flash
 - Could invalidate warranty
 - No custom BIOS logos/settings
 - Laptop manufacturers change specifications frequently
 - Usually use brand-new chipsets without immediate OSS support (e.g. Intel 5100 wifi, Atheros wifi, Attansic Ethernet)
- Force upgrade to newer OS
 - So unlike most embedded projects, ThinIT generally needs to run more cutting edge code.

Perils of upgrade to newer OS

- NetBSD 3.1 didn't support WEP with iwi(4) – forced to switch to 4.0_BETA2.
 - Meant lot of work in short time against tight deadlines
 - Compressed vnds broken at switch – bad timing!
- Meant new Linux emulation (SuSE 10 vs 9)
 - More to chop out!
- New Citrix ICA client
 - Required more Linux libraries

Perils of upgrade to newer OS

- Needed new Atheros and agp drivers – forced to switch to 5.0_BETA
 - Need to rework all existing patches against src and pullup drivers from -current
 - vnd encryption
 - Open-source ath(4) HAL
 - Attansic Ethernet
 - Make autoconf messages quieter
 - Allow quiet boot messages to be forced on in the kernel as kernel could be loaded from multiple bootloaders
 - Undo few things prohibited by default in 5.0 (e.g. re-mount filesystem read-only)
 - Specify multiple resolutions for vesafb so that same kernel can be used on normal and widescreen screens neatly

Problems hit against

- Forced to switch to X.org from Xfree86 (widescreen modes, new chipsets)
 - pkgsrc-based for NetBSD 4.0
 - Actually very painless
 - Made module generation much easier as provides a clear list of components and their dependencies
 - Constantly moving target
 - Module size increased (5.7MB vs 3.7MB) – mainly due to including more fonts and including more libraries
 - Now included in main system for NetBSD 5.0
 - Updated less often
 - Supports DRM
 - Easy to cross-build
 - v2.08 still uses pkgsrc version (will switch back later)

Problems not easily solved

- pkgsrc not designed for embedded system
 - Large dependency lists (e.g. gtk2+ is 33+ MB, got this down to 3.5MB ThinIT module)
 - Options framework not widely used enough
 - Packages include everything needed for development (e.g. header files, static libraries)
 - Mitigated by Makefile.vnd described earlier

Problems not easily solved

- Dependence on Linux emulation for Citrix ICA and Opera
 - Means tied to x86
 - NetBSD 5.0 does not support Linux 2.6 emulation
 - Unable to use latest Citrix ICA client
 - Opera do not not want to pursue a native version of their browser at this point in time
 - After more work shrinking module sizes, we might try switching to Firefox (or Google Chrome?)
- Precedence is a Citrix Global Alliance Partner
 - Good reputation within Citrix UK means we might get source (\$20k last time)

Exciting NetBSD developments

- PUFFS/refuse
 - ntfs-3g (r/w NTFS) useful for dual booting
 - Lots of cool filesystems that could be exported to ICA and RDP sessions
 - gphotofs (PTP cameras that are not mass-storage)
 - ntfs-3g (access local data on dual boot machine)
 - obexfs (mobile phones)
 - psshfs (mount remote data over ssh)
 - Could be used as basis for amd replacement
 - Would allow NFS to be removed from ThinIT kernel
 - amd is overkill for mounting USB pen drives on demand

Exciting NetBSD developments

- RUMP (Runnable Userspace Meta Program)
 - Allows kernel code to be compiled into userland program
 - Fantastic for debugging (single step with gdb)
 - A good way to access untrusted filesystems
 - e.g. `rump_ffs /dev/sd0e /mnt`
- Video4Linux2 framework
 - `uvideo(4)` allows access to modern webcams
 - Much better video conferencing and streaming

Exciting NetBSD developments

- Journaling FFS (WAPBL)
 - Currently use FFS on flash storage mounted read-only; switch to read-write to save settings then switch back
 - ThinIT machine should be able to be switched off any time. Currently small window where filesystem would be unclean (esp. during update process)
 - WAPBL avoids the need for fsck and switching between r/o and r/w
- HAL to detect device insertion automatically
 - Core part of netbsd-desktop project

Future developments for ThinIT

- Reduce reliance on Ethernet
 - 3G integrated or over Bluetooth
 - OpenVPN
- Network 'master' mode
 - One client provides services for others on LAN
 - Need DHCP, NAT, OpenVPN, firmware updates (bozohttpd in 5.0 good for this)
- Support more esoteric peripherals
 - Interactive whiteboards used widely in education

Future developments for ThinIT

- Get “Citrix Ready” certification
 - Just need to fix a problem with Linux emulation
- Switch to gtk2
- Rewrite local client management so can be run on Windows for remote configuration
- Get DRM/Xv working for better video playback
- Track NetBSD developments (of course)

Improvements since Sep 2007

- “Slow releases. 4.0 very late. When 5.0?”
 - Put 4.0 down to experience
 - 5.0 releng process much slicker and better managed
 - (seems churlish to complain too loudly, there's only been 3 ThinIT releases in that time too)

Improvements since Sep 2007

- “Too many developers working at the cutting edge without backporting”
 - Because 4.0 release process was so slow, -current was too different
 - Excitement about the huge step forward with 5.0 drives development; more developers are running it

Improvements since Sep 2007

- “Difficult to fund development”
 - TNF employed ad@ full-time for SMP development with great results.
 - New, expanded board and successful fund raising means more focus
 - GSoC is potentially a good model for funding small development

Improvements since Sep 2007

- “BSD licence clearly better than GPL, but advertising clause is difficult to support (list of names larger than the advert!”
 - NetBSD has switched to 2-clause BSD licence
 - Actively contacting other contributors to ask them if they are willing to remove their names

Conclusion

- NetBSD is excellent for embedded work
 - Quick to develop on
 - Clean code
 - Powerful bulk and cross-building tools
- BSD as whole ideal for product development
 - Commercially friendly licence
 - Integrated kernel/userland
- Has familiar problems seen throughout OSS
 - Lack of device drivers for new hardware
- NetBSD 5.0 is a huge leap forward for embedded and traditional desktop/server systems

ThinIT – lose the wait

- <http://www.fastclients.co.uk/>
- <http://www.thinit.info/>

