NanoBSD and the art of timekeeping

FOSDEM 2012
NanoBSD and the art of timekeeping

• Rudi van Drunen

• Edu: Electronics Design Engineer

• Senior Consultant & CTO Competa IT
  • Bridging the Gap between Business and Technology

• CTO XlexiT Technology B.V.
  • Wireless / Embedded / Networking

• Tech Guru Wireless Leiden
  • Largest wireless community network in NL

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    • Bridging the Gap between Business and Technology
    • YAY: We’re hiring (ao. developers)
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Agenda

- The story: Motivation
- The case: A NTP appliance
- The hard work: NanoBSD
- The results: pretty graphs
- The Fun: A Demo ??
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Time Nuts (1)

Tom van Baak

Cesium cell

Rubidium Clock

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Slide 5
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Time Nuts (2)

http://www.leapsecond.com/great2005

Kids, Clocks, and Relativity on Mt Rainier
Three Cesium Clocks: Red Green Blue & Mean
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I want to be on time...

• So do my systems ...  
  • logging  
  • jobs  

• syncing clocks  
  • local : networked  
  • global : networked
NTP

- NTP (Network time protocol)
  - accuracy: 10’s of ms .. < 1 µs
  - 10..20 million servers / clients
  - runs on every OS :-)
  - now in version 4 (ntp4)
- port 123 (tcp/udp)
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NTP

Peer 1  Filter  NTP msgs  Timestamps
Peer 2  Filter
Peer 3  Filter

Selection algorithm
Comb algorithm

Phase / Frequency
Locked Loop
Loop filter

Variable Frequency
Oscillator
Clock Discipline
why?

- Better than using Internet NTP
- Fun and uses no internet :-)  
  - logging (timestamps)
  - stock trading
  - radio / tv
  - datalogging / measurement / control
  - “trajectcontrole”
- gaming
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Building a stratum 1

- Small embedded board
  - SC520 processor
    - High res timer
  - GPS as time source
    - NMEA + PPS output
- Other time sources
  - DCF 77 receiver (Easy using a Conrad receiver on serial)
  - LORAN C receiver (Using SDR)
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Soekris 4501 (1)
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Soekris 4501 (2)
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GPS 18 OEM

- Garmin hockey puck GPS
- GPS 18 lvc
  - 5V power supply
  - serial output
    - NMEA sentences 4800 bd
  - PPS line (TTL (5V) level)
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Connection

- GPS
  - Serial port (Tx / Rx line of UART)
    - 4800 baud NMEA sequences
    - $GPRMC,113425,A,5210.7572,N,00429.7643,E,000.1,330.3,101209,001.0,W*64
  - DCD line of UART
    - pulse-per-second (start of UTC)
- Power
  - 5 Volts to GPS from board

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Extra PPS accuracy

- Use high-res timer on SC520
- Kernel patch by PHK
  - OPTIONS CPU_ELAN
  - OPTIONS CPU_SOEKRIS
  - OPTIONS CPU_ELAN_PPS
- pps wired to GPIO-0 pin and to the TIMER1IN pin of the SC520
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Software (1)

• Embedded distribution
  • nanobsd (see handbook, std. distro)
    • config kernel straightforward
      • PHK patches
    • config userland to include ntp
      • NTP needs drivers for PPS_API and NMEA (use ports collection)
  • define device links for /dev/gps0 /dev/pps
  • sysctl.conf:
    • machdep.elan_gpio_config=-----P..................
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Software (2)

- ntp.conf
  - Select right clock mode
    - Local NMEA clock (mode 20)
    - Local PPS discipline (mode 22)
  - Select fudge factor
    - delay between UTC second and rising edge pps (datasheet gps)
  - Set logging /statistics file locations
  - Set security and access from other hosts
  - Define (internet ?) peers
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configs

timelord# more /etc/ntp.conf
#
server 127.127.20.0 prefer minpoll 4 maxpoll 4
fudge 127.127.20.0 timel 0.000015
server 127.127.22.0 minpoll 4 maxpoll 4
#
driftfile /etc/ntp/ntp.drift
statsdir /etc/ntp/
#
statistics clockstats
statistics rawstats
statistics loopstats

timelord# more /etc/devfs.conf
# Let NTP know where to find its clock
link cuad1 gos0
link elan-mmcr pps0
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BSD

• One (1) distribution
• Clean version control
• Simple build
  • Kernel
  • Userland
• Experience!
NanoBSD

- A Script in the BSD (source) tree
  - `/usr/src/tools/tools/nanobsd/`
  - Builds a complete system
    - result: Flash image
  - Takes a config file
  - Takes packages to be included
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Disk

- Flash
  - Reliability, NO MOVING PARTS
  - Power / heat
  - Wear
    - Flash: -noatime -ro
    - r/w : use memory filesystem
    - Enable write only when needed
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nanoBSD (flash)Disk

![Diagram of nanoBSD system layout](image)

- nano system #1
- /cfg
- NANO_IMAGES=2
- stored data

NANO_CODESIZE

NANO_CONFFSIZE

NANO_DATASIZE

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nanobsd

- Usage: $0 [-bikqvw] [-c config_file]
  
  -b suppress builds (both kernel and world)
  -i suppress disk image build
  -k suppress buildkernel
  -n add -DNO_CLEAN to buildworld, buildkernel, etc
  -q make output more quite
  -v make output more verbose
  -w suppress buildworld
  -c specify config file
  -h Display usage information.
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config file

# NANO_NAME=myconf
# options passed to buildworld
# CONF_BUILD=
# options passed to installworld
# CONF_INSTALL=
# options passed to buildworld / installworld
CONF_WORLD='NO_MUPPET=YES'
#
NANO_KERNEL=MY_NANO_KERNEL
FlashDevice Sandisk 512M
#
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Configuring Media

• Define Flashdevice
  • FlashDevice <vendor> <ident>
  • in file FlashDevice.sub

• Total sectorcount (diskinfo(8))
  • NANO_MEDIASIZE

• Some bioses need explicit
  • NANO_HEADS
  • NANO_SECTORS
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nanoBSD (flash)Disk

boot0

- nano system #1
- /cfg

NANO_IMAGES=2

- nano system #1
- nano system #2
- /cfg

NANO_IMAGES=2

- nano system #1
- /cfg
- stored data

NANO_CONF_SIZE

- nano system #1
- nano system #2
- /cfg
- stored data

NANO_CODE_SIZE

NANO_CONF_SIZE

NANO_DATA_SIZE

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config partition

- Files for /etc
- r/w mounted during boot

  - vi /etc/ntp.conf
  - mount /cfg; cp /etc/ntp.conf /cfg;
  - umount /cfg
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ramdisk

• /etc
  • default 5 Mbytes
  • NANO_RAM_ETCSIZE=40960

• /var
  • NANO_RAM_TMPVARSIZE=40960
customizing nano

```bash
#
cust_motd () {
    echo "My new MOTD" > ${NANO_WORLDDIR}/etc/motd
}
customize_cmd cust_motd
#
# no VGA
customize_cmd cust_comconsole
# ssh in as root
customize_cmd cust_ssh_root
# install from ../nanobsd/Files
customize_cmd cust_install_files
```
steps in building

clean_build
make_conf_build
build_world
build_kernel
clean_world
make_conf_install
install_world
install_etc
setup_nanobsd_etc
install_kernel
run_customize
setup_nanobsd
prune_usr
run_late_customize
create_${NANO_ARCH}_diskimage
last_orders
Some admin scripts

- `change_passwd`
- `save_sshkeys`
- Update
  - `updatep1`
  - `updatep2`
New software Please!

• How update a once running nano?

  • `ssh nanobox cat _.disk.image.gz | zcat | sh updatepl`
OK, Let’s go!

• Define target Flash size & conf
• Build image
  • `sh nanobsd -C <nanoconfigfile>`
• Coffee!
• Write image to flashcard
  • `dd if=/usr/obj/nanobsd.full/_.disk.full of=/dev/da0 bs=64k`
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OK, back to reality

• Does it work ?!
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Test

timelord# tail -f /var/log/messages

Dec 10 11:16:35 timelord kernel: Timecounter "ELAN" frequency 8333333 Hz quality 1000
Dec 10 11:16:35 timelord kernel: Timecounters tick every 6.666 msec
Dec 10 11:16:35 timelord kernel: Elan-mmcr driver: MMCR at 0xc59e4000. PPS support.
Dec 10 11:16:35 timelord kernel: Elan-mmcr Soekris net45xx comBIOS ver. 1.33 20080103 Copyright (C) 2000-2007
Dec 10 11:33:47 timelord ntpd[536]: time reset +957.271867 s
Dec 10 11:48:53 timelord ntpd[536]: time reset -1.005068 s
Dec 10 11:48:53 timelord ntpd[536]: kernel time sync status change 2001

timelord# cat /dev/gps0
$GPRMC,131244,A,5210.7630,N,00429.7604,E,000.2,166.5,101209,001.0,W*67
$GPRMC,131245,A,5210.7630,N,00429.7603,E,000.3,166.5,101209,001.0,W*60
$GPRMC,131246,A,5210.7629,N,00429.7602,E,000.4,166.5,101209,001.0,W*6D

timelord# ntpq -p
remote refid st t when poll reach delay offset jitter
+GPS_NMEA(0) .GPS. 0 1 1 16 377 0.000 0.003 0.015
oPPS(0) .PPS. 0 1 4 16 377 0.000 0.002 0.015

timelord# ntpmtime
ntp_gettime() returns code 0 (OK)
time cecb7092.2d69f480 Thu, Dec 10 2009 13:05:22.177, (.177398329),
maximum error 1018 us, estimated error 15 us, TAI offset 0
ntp_adjtime() returns code 0 (OK)
modes 0x0 (),
offset 1.623 us, frequency -6.086 ppm, interval 1 s,
maximum error 1018 us, estimated error 15 us,
status 0x2001 (PLL,NANO),
time constant 4, precision 0.001 us, tolerance 496 ppm,
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Results

- Stratum1 NTP server
  - EUR 300
  - max error < 5 µs
  - a weekend of fun!
Accuracy / Offset

loopstats file:

55175 73274.572 0.000037798 -6.205 0.000015259 0.000611 4
<date><time (s)><clock offset(s)>freq offset (ppm)>jitter (s)>wanderer (ppm) clock discipline>
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 pll correction

Compare this to the ambient temperature graph :-)

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Additions

- Webinterface
- LCD + buttons
- Better crystal stability (lowering jitter)
  - Crystal Oven (10 MHz)
  - Rubidium clock from E-bay (ask me !)
  - TAPR clock module synthesizer
    - 10 MHz -> 33.333 MHz
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Thanks to

- Competa IT
  - http://www.competa.com

- Paul Henning-kamp
- The FreeBSD Crew
- USENIX
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Any Questions ...
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resources

- time-nuts
  - http://www.leapsecond.com

- ;login: article
  - http://competa.com/downloads/Articles/
    USENIX_2009-08_a_home_built_NTP_appliance.pdf

- config files
    index.html