im·mu·ta·ble FreeBSD ĭ-myoō′tə-bəl

Experiments building & running immutable infra

Not subject or susceptible to change.

Coimbra EuroBSDcon 2023

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Automater of Things

Professor of Enterprise Yak Grooming

https://git.sr.ht/~dch/euroBSDcon2023/

https://people.freebsd.org/~dch/talks/euroBSDcon2023/immutable.pdf


A DON SIMPSON/ JERRY BRUCKHEIMER PRODUCTION
A FILM BY TONY SCOTT
WILL SMITH GENE HACKMAN
ENEMY OF THE STATE

Principles

“idempotent, repeatable, composable, loosely coupled”

FreeBSD is ideally suited to immutable infrastructure, with powerful primitives

- jails, zfs, boot environments
- poudriere for building complete systems

minimise runtime tooling and ops effort

- preferring up-front dev effort
- let the network do the heavy lifting
- minimise the moving parts
- automate the deploys
- assume fungible hardware

Plumbing

- Anycast, BGP
- Load balancers
- Mesh VPN and DNS

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Networking – it just works™

- AnyCast or GeoDNS + healthcheck failover
- 3 global regions (EU, Americas, Asia)
- ISP router provides iBGP within region to servers
- Servers run haproxy to jails
- Jails are linked via ipv6 mesh network

BGP using bird

```
# http://bird.network.cz/

filter packet_bgp {
  if net = {{ net.bgp.public_ipv4 }}/32 then accept;
}

protocol bgp {
  export filter packet_bgp;
  local as {{ net.bgp.local_as }};

  source address {{ net.private.ipv4 }};
  neighbor {{ net.bgp.neighbor }} as {{ net.bgp.upstream_as }};
  password "{{ net.bgp.md5_password }}";
}
```

The Load Balancer

- Present on each server
- Starts before bird BGP announcer
- sends traffic to nearest “up” jail even if not local
- haproxy has awesome lua integration

```
397 backend couch_be
398   option          httpchk       GET /_up
399   http-check      expect        status 200
400   http-check      disable-on-404
401   # prefer front end nodes for consistent performance and less race
402   # condition risk from concurrent activities on front end nodes
403   # these vars are set in either group_vars/all.yml or overridden in
404   # host_vars/*.yml
405   server          c01_couch [{{ config.couchdb.nodes.c01 }}]:{{ config.couchdb.port }}  check observe layer7
406   server          c02_couch [{{ config.couchdb.nodes.c02 }}]:{{ config.couchdb.port }}  check observe layer7
407   server          c03_couch [{{ config.couchdb.nodes.c03 }}]:{{ config.couchdb.port }}  check observe layer7 back
```

Load Balancers have 2 sides

```
391 frontend couch_fe
392   bind            {{ net.private.ip.haproxy }}:5984
393   http-request    add-header    x-forwarded-port          %[dst_port]
394   http-response   add-header    x-couch                   {{ inventory_hostname }}
395   default_backend couch_be
396
397 backend couch_be
398   option          httpchk       GET /_up
399   http-check      expect        status 200
400   http-check      disable-on-404
401   # prefer front end nodes for consistent performance and less race
402   # condition risk from concurrent activities on front end nodes
403   # these vars are set in either group_vars/all.yml or overridden in
404   # host_vars/*.yml
405   server          c01_couch [{{ config.couchdb.nodes.c01 }}]:{{ config.couchdb.port }}  check observe la
406   server          c02_couch [{{ config.couchdb.nodes.c02 }}]:{{ config.couchdb.port }}  check observe la
407   server          c03_couch [{{ config.couchdb.nodes.c03 }}]:{{ config.couchdb.port }}  check observe la
```

Jails

- How to find the jails
- Immutability
- Deployment

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Exposing Jail State to LBs

```
curl -s localhost:8000 | jq '."jail-information"[][] | select(.name=="www")'
```

```
#!/bin/sh

while :; do
    json=$(jls -vd --libxo json)
    length=$(echo $json | wc -c)
    printf "HTTP/1.1 200 OK\r\nContent-Length: %s\r\n\r\n%s" \
        $length "$json" \
        | nc -lN 8000
    echo ok
done
```


```
{
  "jid": 6,
  "hostname": "www",
  "path": "/jails/instances/13.2-RELEASE-arm64-aarch64/www",
  "name": "www",
  "state": "ACTIVE",
  "cpusetid": 5,
  "ipv4_addrs": [
    "100.64.186.216"
  ],
  "ipv6_addrs": [
    "fca2:927d:4d9b:bbdb:fdd2::bad8"
  ]
}
```

Apps

- Immutability
- Packaging
- Deployment

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Immutable Apps – a Study

- 2 web servers tested
- 8 databases tested
- many custom applications

- a general approach emerges

Immutable Apps – a Study

- Databases are much trickier
- More mutable state
- Harder to load balance
- Lots of zfs tricks
  - FoundationDB, CouchDB, MariaDB, Postgresql, Graylog, MongoDB, ElasticSearch, OpenSearch

Jail & split (im)mutable data

```
dch@continuity /> zfs list -o mounted,canmount,jailed,name,mountpoint |grep -i jail | column -t
MOUNTED  CANMOUNT  JAILED  NAME                                                MOUNTPOINT
no       off       off     zroot/jailed                                        none
no       on        on      zroot/jailed/forgejo                                /var/db/forgejo
yes      on        on      zroot/jailed/hedgedoc                               /var/db/hedgedoc
no       on        on      zroot/jailed/postgres                               /var/db/postgres
no       on        on      zroot/jailed/softserve                              /var/db/softserve
yes      on        on      zroot/jailed/sync                                   /var/db/sync
yes      on        off     zroot/jails                                         /jails
no       off       off     zroot/jails/downloads                               /jails/downloads
yes      on        off     zroot/jails/downloads/13.2-RELEASE-arm64-aarch64    /jails/downloads/13.2-RELEASE-arm64-aarch64
no       off       off     zroot/jails/instances                               /jails/instances
yes      on        off     zroot/jails/instances/13.2-RELEASE-arm64-aarch64    /jails/instances/13.2-RELEASE-arm64-aarch64
yes      on        off     zroot/jails/instances/13.2-RELEASE-arm64-aarch64/hedgedoc    /jails/instances/13.2-RELEASE-arm64-aarch64/hedgedoc
yes      on        off     zroot/jails/instances/13.2-RELEASE-arm64-aarch64/invidious   /jails/instances/13.2-RELEASE-arm64-aarch64/invidious
yes      on        off     zroot/jails/instances/13.2-RELEASE-arm64-aarch64/meringovia  /jails/instances/13.2-RELEASE-arm64-aarch64/meringovia
yes      on        off     zroot/jails/instances/13.2-RELEASE-arm64-aarch64/sync        /jails/instances/13.2-RELEASE-arm64-aarch64/sync
yes      on        off     zroot/jails/instances/13.2-RELEASE-arm64-aarch64/www         /jails/instances/13.2-RELEASE-arm64-aarch64/www
no       off       off     zroot/jails/templates                               /jails/templates
yes      on        off     zroot/jails/templates/13.2-RELEASE-arm64-aarch64     /jails/templates/13.2-RELEASE-arm64-aarch64
```

Immutable Apps – zfs magic

- Use jailed zfs nested containers

```
JAILED  CANMOUNT  MOUNTED  MOUNTPOINT          NAME
on      off       no       /var/db             zroot/jailed/graylog_db
on      on        yes      /var/db/graylog     zroot/jailed/graylog_db/graylog
on      on        yes      /var/db/mongodb     zroot/jailed/graylog_db/mongodb
on      on        yes      /var/db/opensearch  zroot/jailed/graylog_db/opensearch
```

- Use **.zfs/snapshot/$NAME** for backups

```
root@i09 /u/h/dch# cd /graylog/var/db/graylog/.zfs/snapshot/
root@i09 /g/v/d/g/.z/snapshot# l
total 43
drwxr-x---  4 848  848     5B Jul  7 08:49 20230831-1425:13.2-RELEASE-p1/
drwxr-x---  4 848  848     5B Jul  7 08:49 20230906-1010:13.2-RELEASE-p2/
drwxr-x---  4 848  848     5B Jul  7 08:49 20230907-1134:13.2-RELEASE-p2/
drwxr-x---  4 848  848     5B Jul  7 08:49 daily-2023-09-10/
drwxr-x---  4 848  848     5B Jul  7 08:49 daily-2023-09-11/
drwxr-x---  4 848  848     5B Jul  7 08:49 daily-2023-09-12/
drwxr-x---  4 848  848     5B Jul  7 08:49 daily-2023-09-13/
```

Immutable Tricks – Summary

- finagle all the config files
- unix sockets & softlinks for /tmp, /var/run etc
- move syslog to network service
- nested zfs datasets for custom perf & tuning
- zfs diff to find mutable locations
- zfs read-only once complete

Container Deploys

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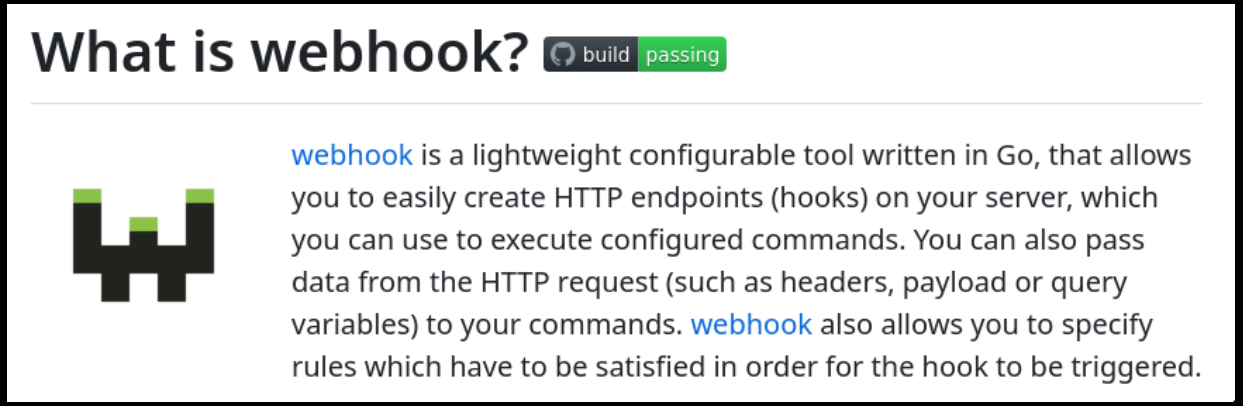
Deploying Containers



- App source code in git repo
- Push code → generate HMAC signed webhook
- haproxy further restricts webhook origin via mTLS & route protection
- Webhook daemon checks HMAC
  - runs CI script and builds new package
  - requests pkg-based deploy

HMAC signed Webhooks for CI

```
# github auto-deploys for internal projects
- id: github
  execute-command: '{{ config.ci.dir }}/src/ansible/github.sh'
  command-working-directory: '{{ config.ci.dir }}/src/ansible'
  include-command-output-in-response: false
  pass-environment-to-command:
  - envname:  CI_REPO
    name:     repository.full_name
    source:   payload
  - envname:  CI_REF
    name:     head_commit.id
    source:   payload
  - envname:  CI_USERNAME
    name:     pusher.name
    source:   payload
  - envname:  CI_USERMAIL
    name:     pusher.email
    source:   payload
  trigger-rule:
    and:
    - match:
        type: payload-hmac-sha1
        secret: {{ config.ci.github_hmac_secret }}
        parameter:
          source: header
          name: X-Hub-Signature
    - match:
        type: value
        value: refs/heads/main
        parameter:
          source: payload
          name: ref
```

Bonus: Arbitrary plays via Webhook

```
---
# vim: filetype=yaml
# docs at https://github.com/adnanh/webhook/wiki
- id: ansible
  execute-command: '{{ config.ci.dir }}/src/ansible/deploy.sh'
  command-working-directory: '{{ config.ci.dir }}/src/ansible'
  include-command-output-in-response: false
  pass-arguments-to-command:
  - source: 'payload'
    name: 'play'
  trigger-rule:
    and:
    # ensures payload is secure -- headers are not trusted
    - match:
        type: payload-hmac-{{ config.ci.cabal_hmac_algorithm }}
        secret: {{ config.ci.cabal_hmac_secret }}
        parameter:
          source: header
          name: x-cabal-signature
    # allows routing via haproxy
    - match:
        type: value
        value: ansible
        parameter:
          source: header
          name: x-cabal-daemon
```

Using pkg-create(8)

```
name:         indie
origin:       indie/indie
comment:      "Zen practice is to open up our small mind – Shunryu Suzuki"
arch:         freebsd:13:x86:64
www:          https://github.com/indiesites/indie
maintainer:   root@indiesites.org
prefix:       /usr/local
licenselogic: single
licenses:     [MIT]
categories:   [indie]
conflict:     indie-*
deps:         {}
flatsize:     0
options:      {git: "GITSHA"}
desc:         <<EOD
Zen is a liberation from time. For if we open our eyes and see clearly, it
becomes obvious that there is no other time than this instant, and that
the past and the future are abstractions without any concrete reality.

– Alan Watts
EOD

message:      <<EOM
Zen is an effort to become alert and awake – Osho.
```

pkg-create(8) and pkg-sign(8)

```
$ pkg create --verbose \
--root-dir ${STAGING} \
--manifest ${MANIFEST} \
--out-dir ${BUILD}
...

# cp ${ARTEFACT} /ci/var/db/ci/pkg/

# pkg repo -o \
   /ci/var/db/ci/pkg \
   /ci/var/db/ci/pkg \
   /usr/local/etc/ssl/keys/pkg.key

…

# jexec $JAIL pkg upgrade -y $foo
```

Apps Summary

- Immutable containerised apps via
  - zfs readonly clone of template “/” for jail
  - nullfs RO mounts for config and www data
  - zfs nested datasets for mutable databases
  - syslog-ng outside jail
  - no internal daemons (syslog, cron, ntp ..)
- Immutable deploys via webhooks and pkg-* tools
- Load balancers and networks make this invisible

Immutable Servers

- ZFS Boot Envs
- Poudriere
- SyncBE deploy
- tarfs(8)

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ZFS Boot Envs

- clone a snapshot of your “/”
- mount it, and edit or update it
- test it in a jail
- activate it and reboot
- woops, roll back, phew!
- ***app data*** is separate and intact

- uses zfs properties:
  - zroot/ROOT/…
  - canmount=noauto
  - mountpoint=/
- uses zpool property:
  - bootfs=zroot/ROOT/yolo

```
dch@akai ~> doas bectl list
BE                                 Active Mountpoint Space Create
13.2-RELEASE-p1_2023-08-18_010858  -      -          1012K 2023-0
13.2-RELEASE-p2_2023-08-18_011113  -      -          2.08M 2023-0
13.2-RELEASE-p2_2023-09-10_213046  -      -          468M  2023-0
current                            -      -          16.8G 2023-0
thirteen                           NR     /          18.7G 2023-0
dch@akai ~> doas bectl activate -t current
Successfully activated boot environment current
for next boot
dch@akai ~> doas bectl list
BE                                 Active Mountpoint Space Create
13.2-RELEASE-p1_2023-08-18_010858  -      -          1012K 2023-0
13.2-RELEASE-p2_2023-08-18_011113  -      -          2.08M 2023-0
13.2-RELEASE-p2_2023-09-10_213046  -      -          468M  2023-0
current                            T      -          16.8G 2023-0
thirteen                           NR     /          18.7G 2023-0
```

Loader Prompt – IPMI supported

poudriere-(devel)

- Build FreeBSD from src
- Build packages from ports tree
- Great doc coverage on wiki
- Build deployable images in many formats
  - memstick, iso
  - zfs dataset
  - tarball

Inputs

- git source & ports tree
- overlay directory for images
  - `boot/loader.conf`
  - `etc/fstab`
  - `etc/rc.conf.d/sshd`
  - `etc/resolv.conf`
  - `usr/local/bin/sync-be **`
  - `usr/local/etc/pkg/repos/FreeBSD.conf`
- a list of packages we want to build
  - `sysutils/spiped`
  - `sysutils/tmux`
  - `...`

Usage – OS + Package Build

```
# poudriere jail -c -j 13_2_builder_amd64 \
   -v releng/13.2 \
   -m git+https \
   -b -K GENERIC

# poudriere bulk -j 13_2_builder_amd64 \
   -f ./packages.lst
```

Usage – Image Build

```
# poudriere image -t zfs+send+be \
  -j 13_2_builder_amd64 \
  -f ./packages.lst \
  -s 4G \
  -h '' \
  -o /usr/local/poudriere/images/ \
  -c overlay \
  -n ${IMAGE}
```

Server Deploys

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Deploy – curl → BE

```
# bectl list
BE Active Mountpoint Space Created
13.1-RELEASE_2023-03-21_152313 - -  836K2023-03-21 15:23
default  NR /  2.24G 2023-03-21 13:49

# curl -#L https://pkg/images/be202303262144.be.zfs \
| /usr/local/bin/sync-be 13.2-RELEASE /etc/syncbe.conf

using config file: /etc/syncbe.conf
receiving full stream of zroot.356600197/ROOT/default@202303262144 \
into zroot/ROOT/13.2-RELEASE@202303211523
##############   70.1%
...
received 1.77G stream in 35 seconds (51.7M/sec)
...
```

Config Hacking

- Same tricks as usual
  - softlinking mutable dirs out into a separate location
  - read-only zfs datasets
  - unix sockets everywhere, or network services
  - nullfs mounts to clean things up
- Works for Appliances, less for Generic Servers
- Dammit.

Enter sync-be

- Klara Systems tool
  - creates a new boot env
  - from your stdin-supplied zfs
  - mounts it temporarily
  - transfers in your local /etc/ /usr/local/* changes
  - unmounts the BE
  - temporarily activates it

Deploy – pristine BE → existing state

```
…
copying boot/loader.conf to /tmp/QilKale4/boot/loader.conf
copying boot/loader.conf.d to /tmp/QilKale4/boot/loader.conf.d
copying etc/login.conf.db to /tmp/QilKale4/etc/login.conf.db
copying etc/pwd.db to /tmp/QilKale4/etc/pwd.db
copying etc/spwd.db to /tmp/QilKale4/etc/spwd.db
...
copying root to /tmp/QilKale4/root
zfs bootenv is successfully written
ready for reboot!
# reboot
```

tarfs(8)

- Mount a tarball as a (readonly) filesystem
- Can be jailed & nullfs-mounted
- Built by Klara Systems and Juniper Networks
- Coming in 14.0-RELEASE
- May not be as fast as other filesystems yet
- Only supports plain tarball, or tar+zstd only

tarfs(8) in action

```
# unxz < /dl/13.2-RELEASE-arm64-aarch64/base.txz \
   > 13.2-RELEASE.tar
# mkdir jail
# mount -t tarfs 13.2-RELEASE.tar jail
# mount -t devfs devfs jail/dev
# mount -t tmpfs tmpfs jail/tmp

# jail -cv name=tar path=jail command=/bin/sh
jail_set(JAIL_CREATE) persist name=tar path=jail
created
run command in jail: /bin/sh
```

tarfs(8) in action

```
… run command in jail: /bin/sh

# mkdir /coimbra
mkdir: /: No such file or directory
# df -h / /tmp /dev
Filesystem          Size    Used   Avail Capacity  Mounted on
13.2-RELEASE.tar    929M    929M      0B   100%    /
tmpfs                20G    4.0K     20G     0%    [restricted]
devfs               1.0K      0B    1.0K     0%    [restricted]
#
```

Credits & Thanks

- malloc(questions[])
- free(&dave)
- madvise(*social)

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