GOT

The Game of Trees Hub

Stefan Sperling <stsp@openbsd.org>

EuroBSDcon 2025

What is Game of Trees?

Game of Trees (Got) is a version control system which prioritizes ease of use and simplicity over flexibility.

- Compatible with Git repositories and Git network protocol.
- Designed with OpenBSD developer use cases in mind.
- OpenBSD-style C code base.
- Extensive use of OpenBSD pledge and unveil.
- ISC licence.
- -portable version for Linux, MacOS, {Free,Net,Dragonfly}BSD.

Nice things others have said about Game of Trees

"May I just say swoon?"[1]
– Aaron Poffenberger in 2019

---

[1]https://web.archive.org/web/20240614075550/http:
//akpoff.com/archive/2019/mini_review_of_tog.html

Nice things others have said about Game of Trees

"The project's first line about prioritisation is diplomatic, but software is often written to solve a problem."[2]
– Oliver Lowe in 2020

---

[2] https://olowe.co/2020/10/got.html

Nice things others have said about Game of Trees

"I recall when Stefan first announced this. I was very happy that it was him, because (...) I knew he wouldn't just wade in and make silly mistake after mistake."[3]
– Alex Holst in 2023

---

[3]https://lobste.rs/s/nq49si

Nice things others have said about Game of Trees

"if you're looking for a no frills VCS, Got may be just what you need."[4]
– Simon Harrison in 2025

[4]https:
//simonh.uk/2025/06/08/trying-out-openbsd-game-of-trees-got/

The Game of Trees Hub

Git repository hosting site based on Game of Trees and OpenBSD.
Goals:

- Provide hosting to people who are not already self-hosting.
- Host both open source projects and private projects.
- Be a live test bed for Game of Trees to improve quality.
- Be useful and reliable enough to serve a steady user base.
- Grow to a comfortable size, not indefinitely.

The Game of Trees Hub: Financial goals

Running a hosting site costs money and time.

- We want to be funded by users and supporters, not investors.
- Keep our finances transparent to the general public.
- Charge users to cover hosting costs and expenses.
  - Do not charge anyone who was merely given commit access.
- Use surplus funds to support our admins and developers.
  Currently:

  Stefan Sperling
  Thomas Adam
  Omar Polo
  Gonzalo Rodriguez
  Johannes Thyssen Tishman
  Josh Rickmar

Open Collective

◯ open collective

Raise, manage, and disburse money with full transparency.

- Public ledger which displays all financial transactions.
- Our expenses are peer-reviewed within the admin team.
- We collect voluntary contributions which support the project.
  - Thank you OpenBSD Amsterdam, Pushover LLC, Mark Jamsek, Paul Kelly, Stöge, phildom, Greg Stueck, Matthieu Herrb, Lucas Raab, and many others I cannot fit here.
- Project status announcements are sent to our contributors.

See https://opencollective.com/gothub

Fiscal Self-Hosting

 We are using my company as fiscal host.

- A fiscal host owns the collective's bank account and is the legal entity which can be invoiced and deals with taxes.
- My company is a software consultancy based in Brussels.
- No external investors or stakeholders. Fully owned by me.
- Collective's bank account kept separate from other activities.

gotd – Game of Trees Daemon

Git repository server which is accessible via SSH.

- Compatible with any Git client implementation.
- Supports multiple users/groups.
- Supports per-repository access permissions.
- The gotsh shell speaks Git protocol on stdin/stdout.
- Can allow anonymous read-only access over SSH.

Presented at FOSDEM 2023:
https://archive.fosdem.org/2023/schedule/event/game_of_trees_daemon/

```
gotsysd(8), gotsys.conf(5)
```

gotsysd is a necessary evil for the Game of Trees Hub.

- Allows configuration of gotd servers without root shell access.
- Controlled by gotsys.conf, which users/admins edit
  remotely and send to the special repository gotsys.git.
- Manages users and groups in /etc/master.passwd.
- Manages authorized_keys files and sshd_config.
- Reconfigures and reloads gotd when gotsys.conf changes.

gotsys.conf syntax
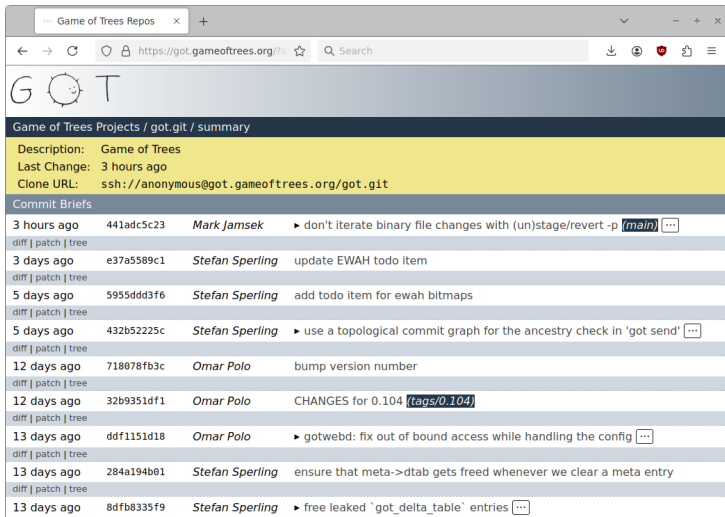
```
group developers

user flan_hacker {
 password "$2b$08$CFWp/ZC.DQi34.iH..."
 authorized key ssh-ed25519 AAAAC3NzaC1...
 group developers
}

repository "src" {
 permit rw :developers
 permit ro anonymous
 notify {
  email to source-changes@example.com
  url "https://example.com" hmac "y6uEZtedpxBW...="
 }
}
```

Documentation:
https://gameoftrees.org/gotsys.conf.5.html

Git repositories in the browser - gotwebd

gotwebd status

The Game of Trees Hub should display repositories on the web.
But gotwebd is not deployed yet:

- gotwebd was incompatible with repository access permissions.
- gotsysd needs support for generating gotwebd.conf.
- Some gotwebd instances are being hammered by aggressive web crawlers and there is no ideal solution for blocking them. We finally do have an effective workaround for this.

gotwebd user authentication

In upcoming got-0.119, gotwebd supports access permissions.
Users can log in over ssh and authenticate to gotwebd via gotsh:

```
$ ssh user@got.example.com weblogin
Login successful.
Please visit the following URL within the next 5 minutes:
https://got.example.com/?login=djEA2KvWaAAAAAAErdZoAAAAAOgDAAAAA...
```

Visiting this URL sets a browser cookie with an access token.

- The token is signed (HMAC SHA256).
- It contains a validity timestamp.
- It contains the UID used for permission checks.

gotwebd user authentication

Authentication can also block web crawlers by requiring public login as "anonymous":

```
$ ssh anonymous@got.gameoftrees.org weblogin
Login successful.
Please visit the following URL within the next 5 minutes:
https://got.gameoftrees.org/?login=djEAz6zWaAAAAAD7rdZoAAAAAgEAAA...
```

This approach works because the bots do not bother to log in. If they did, we could require custom puzzles to be solved before revealing the URL. (But we'd rather not. Bots, please stay away.)

Ideas for the future: Extending Functionality

Most users will expect tools such as:

- An issue/bug tracker.
- A web interface for code review.
- Communication forums of some kind.

We have little hope of implementing such features in a reasonable time frame. For now, our best option is to integrate existing tools people would like to use.

Integrating third party tooling

We could install third-party software via the OpenBSD ports tree to offer additional services, such as:

- Code Review: Gerrit, Reviewboard
- Issues, Wikis: Redmine, TiddlyWiki
- Communication: Mailing lists?

Your ideas about useful tools would be very welcome.
I would rather avoid hosting software which requires moderation effort such as: IRC (Libera), Matrix, Mastodon, ...

Some more ideas for the future

- Custom domain support: We could support users who point their own domains at our servers. We could configure acme-client to obtain certificates for those domains.
- Static web hosting: gotwebd could optionally serve the contents of specific repositories as if they were a static web site, eliminating the need to find another web hosting service for project web sites, project documentation, etc.

Game of Trees Hub Tiers 2025

Hosting fees are estimates based on server rental prices, assuming about 40 VMs per server.
Expenses are somewhat arbitrary but needed since we would like to pay people for their time.

	Small	Medium	Large
Max repository size	300 MB	1 GB	2 GB
Total Repository space	1 GB	6 GB	16 GB
Hosting Fees	€4.00	€6.50	€10.00
Expenses	€4.50	€7.50	€8.00
Result	€8.50	€14	€18
Taxes (21%VAT)	€1.78	€2.94	€3.80
Total per month	€10	€17	€22

Game of Trees Hub Tiers 2025

We also offer "Fancypants" tiers for e.g. business use.

- VM on more expensive servers with fast CPU and ECC RAM.
- Prices exclude VAT. Provide your VAT-ID for 0% VAT.
- Support requests get higher priority.

	Small	Medium	Large
Max repository size	300 MB	1 GB	2 GB
Total Repository space	6 GB	24 GB	40 GB
Hosting Fees	€10.50	€16.50	€19.50
Expenses	€19.50	€24.00	€37.00
Total per month	€30	€40	€60

Our Tiers should evolve over time

We will revise tiers at least once a year.
Goals:

- Adjust prices down if possible.
- We **must** cover hosting costs to avoid running out of funds.
- We should have at least 1000 EUR, ideally 3000 EUR, of Expense funds available per month for maintenance and development work done by multiple people. Below 1000 EUR we are mostly relying on volunteer work.

Roughly 130 regular users or 40 business users would help us meet the 1000 EUR goal. We are far from that right now.

Signing up

- You will need a credit card to purchase a subscription.
- Send email to signup@gothub.org, telling us:
    - Which tier you want.
    - Which subdomain name you want.
    - The initial user name.
    - The initial public SSH key.
- Alternatively: $ ssh signup@gothub.org
  Host key:
  SHA256:SlhsNLc4ZtasXKUmJeUqHHhUdGttyz+NvnfbhJ1VHnY (ED25519)
  Talk to our arc4random-powered chat bot.

See https://gothub.org/signup.html for details.

The first part of my talk ends here.

The second part describes how the service is deployed.
Are we on track regarding time?

https://gameoftrees.org — https://gothub.org

Hosting Setup

When someone books service we create:

- A subdomain: `mydomain.gothub.org`
- A vmm(4) virtual machine on an OpenBSD server.
- An initial `gotsys.conf` in a `gotsys.git` repository.
- An initial user account authenticated by an SSH public key.

Makefiles for scripted VM deployment

Users of the service never see this. It is our admin tooling.

```
|-- Makefile.inc
|-- Makefile.inc.vm
|-- base       # Build OpenBSD VM qcow2 base images.
|   |-- 7.7
|   |   |-- Makefile.inc
|   |   '-- amd64
|   |       |-- Makefile
|   |       '-- Makefile.inc
|   '-- Makefile.inc
'-- t0         # Build qcow2 images for VMs running on server "t0"
    |-- Makefile
    |-- Makefile.inc
    |-- host   # Generate host-side files: pf.conf, vm.conf, ...
    |   |-- Makefile
    |   '-- pf.conf.head
    |-- t0a    # Build qcow2 image for VM "t0a"
    |   '-- Makefile
    |-- t0b    # Build qcow2 image for VM "t0b"
    |   '-- Makefile
```

Declaring a virtual machine

```
.include "../Makefile.inc"

ARCH=amd64
OPENBSD_VERSION=7.7
NUMERIC_VERSION=77
VM_NAME=t0a
MEM_SIZE=1G
GIT_DISK_SIZE=4G
GOTSYS_USER=stsp
GOTSYS_USER_PUBKEY=ssh-ed25519 ...
PASSWD_ROOT=\\\$$2b\\\$$10\\\$$NLC...
GW_IP4=10.205.0.1
GW_IP6=fc00:1::1
INT_IP4=10.205.0.2
INT_IP6=fc00:1::2
INT_IF=tap1
EXT_IP4_SSH_PORT=2221
EXT_IP6=2a00:12e8:201:19:ffff::2
TEMP_DISK_SIZE=1G
SWAP_DISK_SIZE=512M

.include "../../Makefile.inc.vm"
```

Deployment Automation

VMs can be live-patched with pkg_add -u and syspatch.
But usually we build a new base image via scripted autoinstall:

```
# cd deploy/base/7.7/amd64
# make && make install
```

This gives us a fully patched 7.7-release system.
Freshly built got, gotd, gotsysd, and gotwebd packages are
installed which we can patch if needed.

OpenBSD base images

Our qcow2 base images:

- Use a revision number in the file name to prevent booting with a wrong base image.
- Have an associated SSH key which goes directly to root, used during deployment and deleted from the finalized VM.

```
t0$ ls /vm/
base_77_amd64.1.qcow2       base_77_amd64.15.sshkey    t0a/
base_77_amd64.10.qcow2      base_77_amd64.2.qcow2      t0b/
base_77_amd64.11.qcow2      base_77_amd64.3.qcow2      t0c/
base_77_amd64.13.qcow2      base_77_amd64.4.qcow2      t0d/
base_77_amd64.14.qcow2      base_77_amd64.8.qcow2      t0e/
base_77_amd64.14.sshkey     base_77_amd64.9.qcow2
base_77_amd64.15.qcow2      base_77_amd64.qcow2
```

VM disks

Each VM has 4 separate disks:

- root – layered on top of the qcow2 base image.
- tmp – /tmp on softraid crypto with random keys.
- swap – Swap space.
- git – Git repositories and copy of VM's SSH host keys.

The git repository disk

The initial git disk contains just gotsys.git with initial settings.
The git disk is permanent. The others are disposable.

```
# ls -1 /vm/t0a
t0a_disk.qcow2
t0a_disk.qcow2.old
t0a_gitdisk.raw    # never overwritten during make install
t0a_swapdisk.raw
t0a_tempdisk.raw
```

If the git disk is lost, only SSH host keys are lost permanently.
We have backups of all repositories on a dedicated server.

(Re-)Installing a VM

Step 1: Build and install VM disk images and config files.

```
# cd deploy/t0/t0a
# make            # build fresh disk images
# vmctl stop t0a  # stop VM to ensure clean state
# make install    # copy disks to /vm and hostname.tap1 to /etc
```

make targets can also be invoked from parent directory to upgrade
multiple VMs at once.

(Re-)Installing a VM

Step 2: Create and install host-side config files:

```
# cd deploy/t0/host
# make                    # generate pf.conf, vm.conf, hostname.em0
# make install            # cp vm.conf pf.conf hostname.em0 /etc
# pfctl -f /etc/pf.conf
# sh /etc/netstart em0
# sh /etc/netstart tap1
# vmctl reload            # restart all stopped VMs
```

VM upgrades

When an upgraded VM boots with a fresh base image:

- /etc/rc.securelevel mounts the git disk and restores SSH host keys from it.
- gotsysd re-creates missing user accounts, home directories, and authorized keys files, based on contents of gotsys.conf.

Now the upgraded VM runs with an identical configuration.
Downtime during VM upgrades is minimal.

Getting started with a fresh gothub.org VM

Clone gotsys.git with any Git client. Without IPv6, specifying your VM's port number is mandatory.

```
$ git clone ssh://user@example.gothub.org:2221/gotsys.git
```

Add a new repository to gotsys.conf:

```
repository "new" {
 permit rw "user"
}
```

```
$ git commit -a
```

Send the change, and gotsysd will create the repository:

```
$ git push
```

ssh://user@example.gothub.org:2221/new.git can now be used as a Git remote. Its default HEAD is refs/heads/main.

Thank you for listening! Got questions?

https://gameoftrees.org — https://gothub.org