Still All on One Server: Perforce at Scale

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GOOGLE

- Google's mission: Organize the world's information and make it universally accessible and useful.
- The world's premier web search; many other products
- Headquartered in Mountain View, California
- ~25,000 employees worldwide

OVERVIEW

- Perforce at Google
- Performance
- Everything Else

Perforce at Google

PERFORCE AT GOOGLE

- Almost all of Google's projects are in Perforce, and most are in a single depot.
- Our server sees many, many different usage patterns. About half our use comes from scripts and half from interactive users. Most interactive use is from the command line.
- The server holds documentation, data, and non-engineering work as well as code.
- We have a full-time p4 admin team, and lots of additional support from hardware teams, tools teams, and interested individuals.

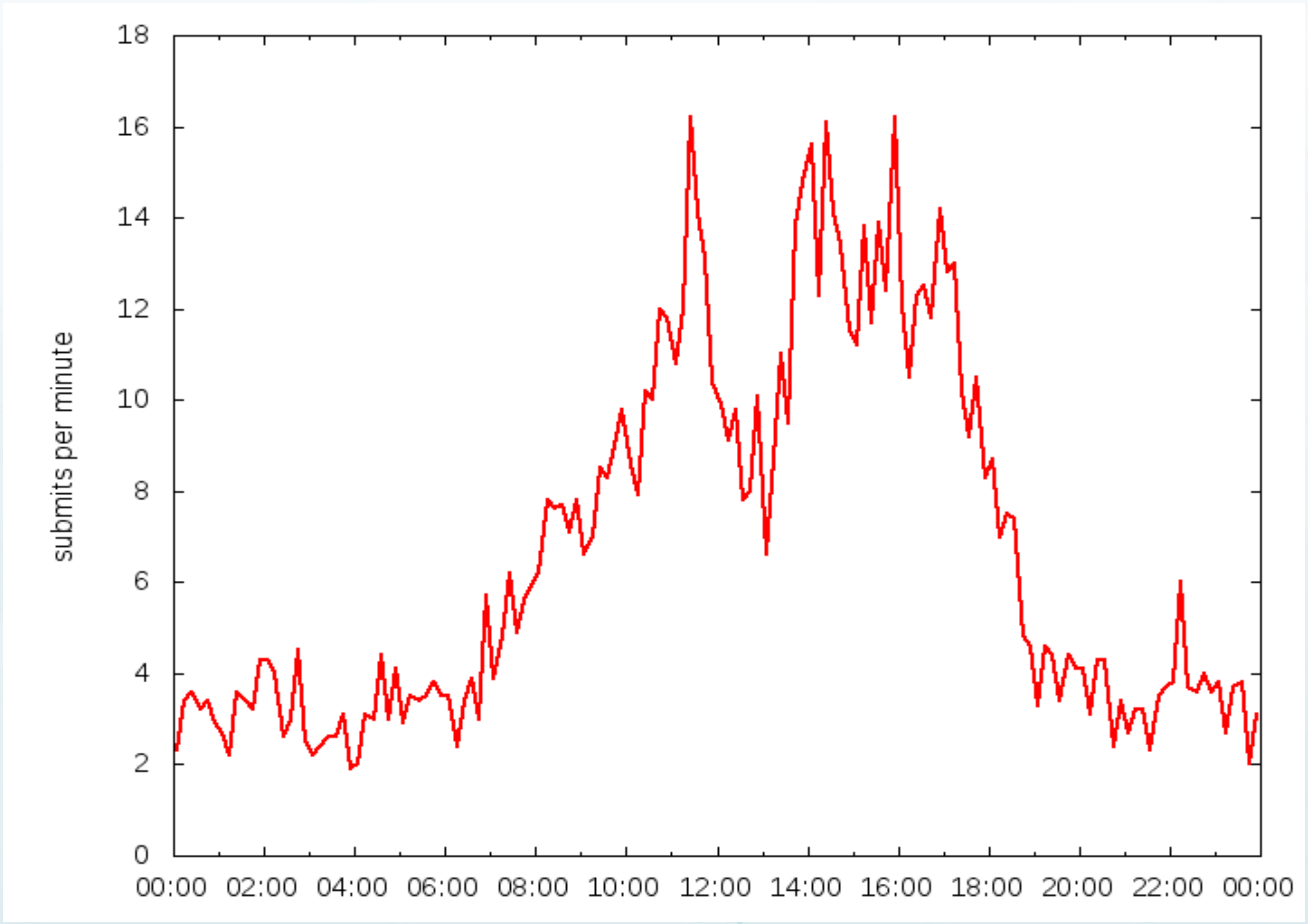
PERFORCE AT GOOGLE: MAIN SERVER

- 16 CPUs, 256 GB memory, Linux
- Metadata on solid state disk
- Depot on network-attached storage
- Logs and journal on local RAID

- This server instance has been in operation for more than 11 years.
- ~10 million submitted changelists

- > 12,000 users
- > 1 TB metadata
- 10-12 million commands/day
- ~10k submits/day

SUBMITS PER MINUTE



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OTHER PERFORCE SERVERS

- ~10 smaller servers, with between 1-25 GB metadata each, all on one machine
- Combined load < 20% of main server
- Metadata on local RAID disk, not solid state
- Same users as main server via P4AUTH
- Very little administrative burden

- 2 readonly replicas
- ~50 proxies

Performance

PERFORMANCE WORK

- Background: database locking and concurrency
- Machine resources
- Perforce, Inc. improvements
- Configurables
- Monitor and if necessary, kill user commands
- Reducing metadata
- Offload work from Perforce
- Multiple servers - maybe

PERFORCE METADATA

- There are about thirty-five database files, with names like **`db.have`**, **`db.labels`**, **`db.counters`**, etc.
- Details about the schema can be found at http://www.perforce.com/perforce/r10.2/schema/index.html
- Information about specific db files is in my white paper.

DATABASE LOCKING

- p4d processes lock database files with either read or write locks using OS-level `flock` calls.
- Long-running commands holding locks block other commands.
- When significant locks are held, some or all other commands hang.
- Write commands (e.g., `submit`) block all other commands. Read commands block write commands but allow reads.
- More detail in **Performance and Database Locking at Large Perforce Sites**, http://www.perforce.com/perforce/conferences/eu/2006/presentations/Google.pdf (Bloch, 2006)

MACHINE RESOURCES

- CPU – generally not an issue for Perforce servers
- Memory – enough to avoid paging
  - Perforce guideline: 1.5k/file (http://kb.perforce.com/article/5)
  - This doesn't apply to large sites (fortunately). Unused table rows, e.g., old branches, are never paged into memory.
- Network – you should check bandwidth and tuning, but this doesn't require frequent attention

MACHINE RESOURCES, CTD.

- Disk I/O – **single most important factor at large sites**
  - recall that concurrency is gated by the time spent by commands holding database locks
  - this time spent is a function of the time the command spends reading and writing to the database
  - faster is better
    - keep database on local, not network disk
    - stripe data across many spindles, e.g., RAID 10
    - for largest sites, use solid state disk, either Flash (best price-performance) or RAM-based (absolute fastest)

THE EASIEST WAY TO IMPROVE PERFORMANCE

Make sure to pick up Perforce upgrades! There have been a steady stream of significant performance improvements over the last five years.

Read the release notes too!

CONFIGURABLES

- Configurables allow some low-level tuning.
- Only use with advice from Perforce product support.
- Introduced and evolved in Perforce 2008.2 through 2010.2. Originally called tunables.
- For more information see “p4 help configurables” and **Perforce Tunables**, http://www.perforce.com/perforce/conferences/eu/2010/Presentations/Michael_Shields-Tunables.paper.pdf (Michael Shields, 2010)

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MONITORING

- Monitoring is an essential part of maintaining any service, Perforce or otherwise.
- Monitoring can page, send email, or create bug reports, depending on the severity of the problem.
- The goal is never to be notified about a problem by one of your users.
- Performance-specific monitoring at Google:
  - commands holding long-running locks (`locks.pl`, in the Perforce Public Depot in //guest/dan_bloch/)
  - commands using more than 3 GB of memory
  - users running many commands in parallel

MONITORING WITH EXTREME PREJUDICE

- Any user’s commands can affect the performance of the server as a whole.
- The MaxResults, MaxScanrows, and MaxLocktime resource limits can be set to kill some of these.
- With work, you can eliminate others, e.g., a spec trigger so the default client doesn’t include //depot/…
- Talk to users. Change use patterns.
- But we still find it necessary to have automated scripts kill commands under some circumstances:
    - long running readonly commands holding locks
    - known bad commands, e.g., “p4 files //…”

MONITORING, CTD.

- **Killing processes can corrupt your database**
- Only killing readonly processes is safe.

- More detail in **Life on the Edge: Monitoring and Running A Very Large Perforce Installation**, http://www.perforce.com/perforce/conferences/us/2007/presentations/DBloch_Life_on_the_Edge2007_paper.pdf (Bloch, 2007)

REDUCING METADATA

- Less data to scan means faster commands.
- Even in cases where it doesn't, it means faster checkpoints, and money saved on expensive storage.
- This reduction can be approached both reactively (cleanups) and proactively (strategies to create less metadata).
- This only applies to metadata. Less depot content doesn't improve performance.

REDUCING METADATA - SPECIFICS

- **Client and label cleanups** – straighforward. Beneficial, but not a performance benefit.
- **Sparse clients**: Ideally, users only need to sync the directories they’re editing.
    - Some build systems provide support for this, e.g. gnumake’s vpath functionality.
    - Google uses a proprietary file system integration.
- **Sparse branches**: Small branches with most of the content coming from the mainline. More valuable: Clients are temporary, but branches are forever.
    - Perforce provides some support: overlay mappings (http://kb.perforce.com/article/890/sparse-branching)
    - Google also has a build integration to specify the mainline changelist level.

OBLITERATES

- Typically used to clean up depot space, or the depot namespace, or remove files with sensitive information.
- Can also be used to reduce metadata.
- Previously very expensive. Now, if you only want to remove metadata, obliterates can be done quickly with the undocumented "–a" (ignore depot content) and "–h" (ignore have table) flags.
- Our largest obliterate cleaned up old branches and removed 11% of the file paths in our depot.
  - Lots of work, including testing and negotiating with release engineers.
- **Obliterates are dangerous. Be careful!**

OFFLOADING WORK FROM PERFORCE

- Replicas – readonly replicas of a Perforce server
  - Supported by Perforce as of 2010.2 (see System Administrator's Guide)
- Other systems – in-house.
  - A file system integration
  - Special-purpose databases which contain Perforce database information. (See also Perforce's P4toDB tool.)
  - Caveat: services like this may poll the server frequently and generate load of their own.

MULTIPLE SERVERS?

- Having more than one server obviously results in less load on each.
- But it usually isn't worth it.
- Use separate servers for independent projects.
- Splitting depots for performance reasons won't offset the costs in user inconvenience and administration.

Non-Performance Issues of Scale

NON-PERFORMANCE ISSUES OF SCALE

- Depot disk space
- Checkpoints
- High availability
- Administrative load

DEPOT DISK SPACE

- Ways of cleaning up disk space:
  - obliterating
  - stubbing out files (http://kb.perforce.com/article/72/making-large-repositories-smaller)
  - moving to less expensive storage with archive depots and "p4 archive" and "p4 restore", as of Perforce 2010.2
  - replacing multiple identical files with hard links
- Use "+S" modifier with care
  - +S only saves the most recent version(s) of file
  - But branched copies of +S files aren't lazy copies
  - So if a file is branched a lot, +S can make it take up **more** space. Possibly a lot more.

CHECKPOINTS

- Checkpointing methods:
  - normal checkpoint – server is unavailable
  - offline checkpoints – create a duplicate database from checkpoint + journal, and checkpoint that
  - Logical Volume Manager (LVM) checkpoints
  - Having tried all the variants, Google currently uses LVM snapshot checkpoints.
- See **Demystifying Perforce Backups and Near Real-Time Replication**, http://www.perforce.com/perforce/conferences/eu/2008/presentations/perforce_richard_baum_whitepaper.pdf (Richard Baum, 2008)

CHECKPOINT ENHANCEMENTS

- We optimize our checkpoints and restores by processing each database file individually, so we can checkpoint and install multiple database files in parallel.
- We checkpoint the standbys at the same time as the main server, so we have a checkpoint even if one job fails.

HIGH AVAILABILITY

- We maintain a hot standby, and have and test a failover plan. See **Perforce Disaster Recovery at Google**, http://www.perforce.com/perforce/conferences/us/2009/Presentations/Wright-Disaster_Recovery-paper.pdf (Rick Wright, 2009)
- We have a test server, which we restore from the main server weekly, so we can test anything in an environment nearly identical to the production server.
- We write postmortems for every outage, with action items to prevent the same thing from happening again.

ADMINISTRATIVE LOAD

- Make all of your servers look the same (disk layout, scripts, etc.)
- Use P4AUTH so user accounts only have to be created once.
- Invest in automating tasks and self-service for users.
- Share all information within the admin team, e.g., we send all Product Support email to a mailing list so all the admins can learn from all the support calls.
- Document everything.

Closing Thoughts

LESSONS LEARNED

- Know as much as you can about what's happening on your server.
- Look at all possible ways of improving performance. There’s no one solution.
- Do cleanups.
- Try to reduce the size of everything (changelists, clients, branches, …).
- Offload work from the server.

CLOSING THOUGHTS

- Our size was enabled because we, as well as Perforce, grew into it. Five years ago, neither Perforce nor Google could have handled a site this size.
- As a pioneer, we’re atypical in that we use home-made solutions for many problems that Perforce now provides its own solutions for.
- In many ways our growth was unplanned. There’s always tension between developing as fast as you can and keeping everything clean and structured. The next big site won’t look like us.
- Choose which elements from our system will be of use to you. The most important thing is understanding your own site’s environment.