






facebook

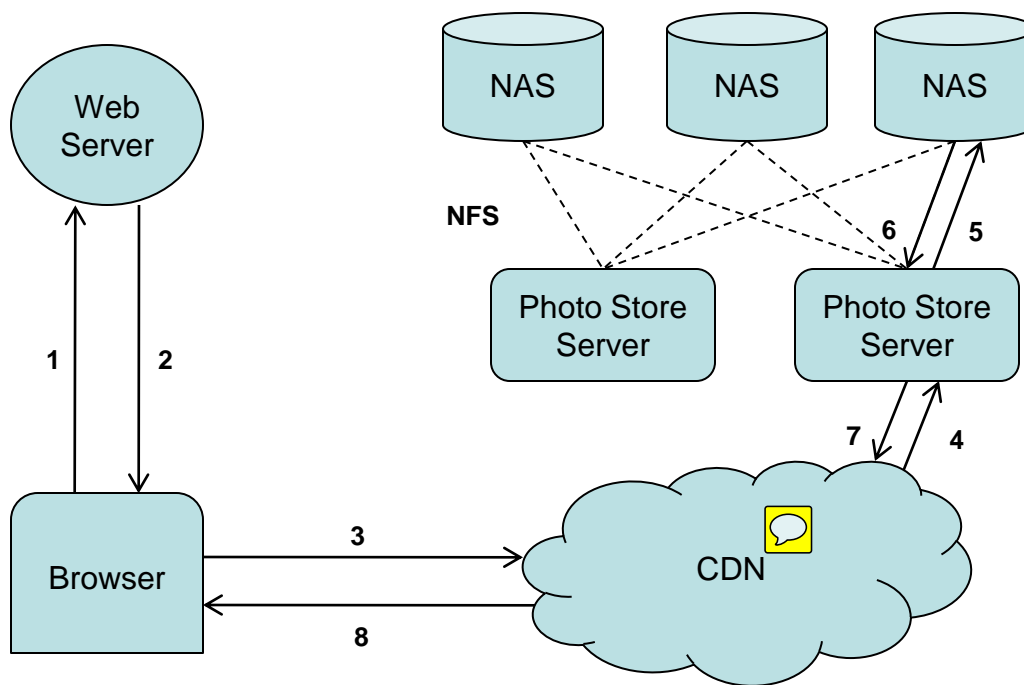
Finding a needle in Haystack: Facebook's photo storage

Doug Beaver, Sanjeev Kumar, Harry C. Li, Jason Sobel, Peter Vajgel


Photos @ Facebook

	April 2009	Current 
Total	15 billion photos 60 billion images  1.5 petabytes	65 billion photos 260 billion images  20 petabytes 
Upload Rate	220 million photos / week 25 terabytes	1 billion photos / week 60 terabytes
Serving Rate	 550,000 images / sec	1 million images / sec

NFS based Design



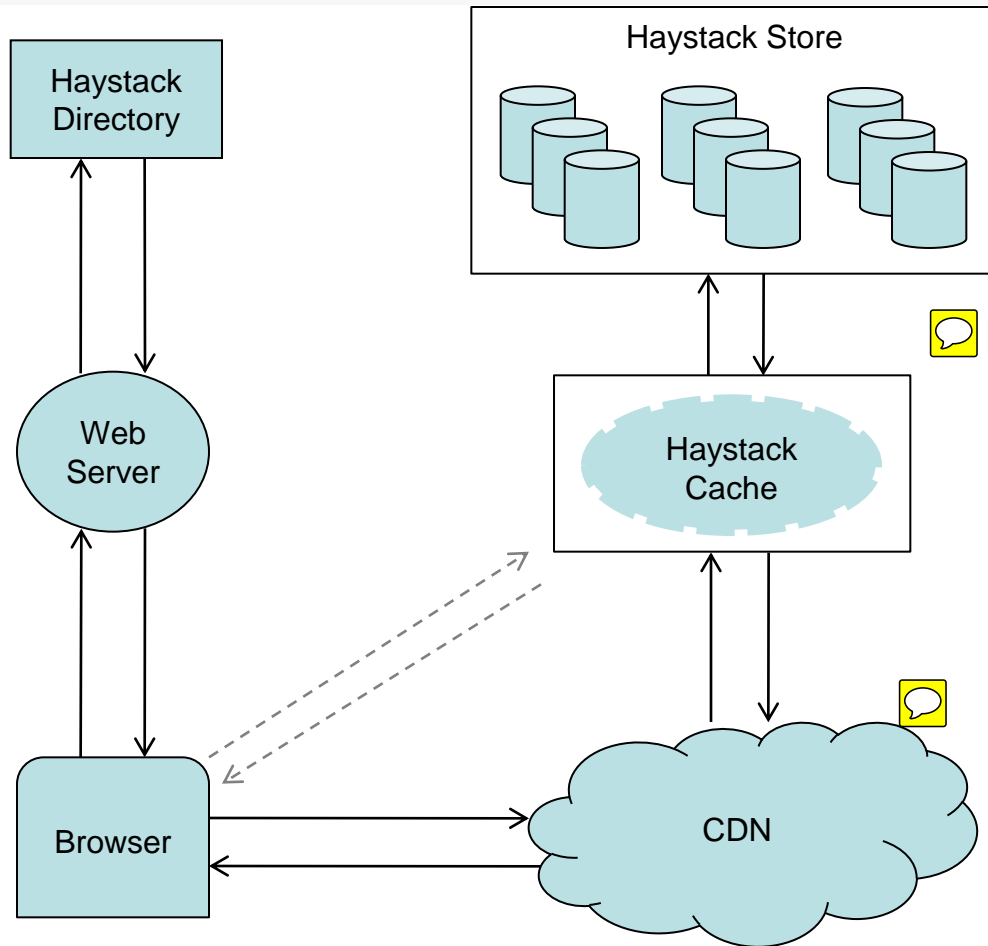
NFS based Design

- Typical website
 - Small working set
 - Infrequent access of old content
 - ~99% CDN hit rate
- Facebook
 - Large working set
 - Frequent access of old content 
 - 80% CDN hit rate

NFS based Design

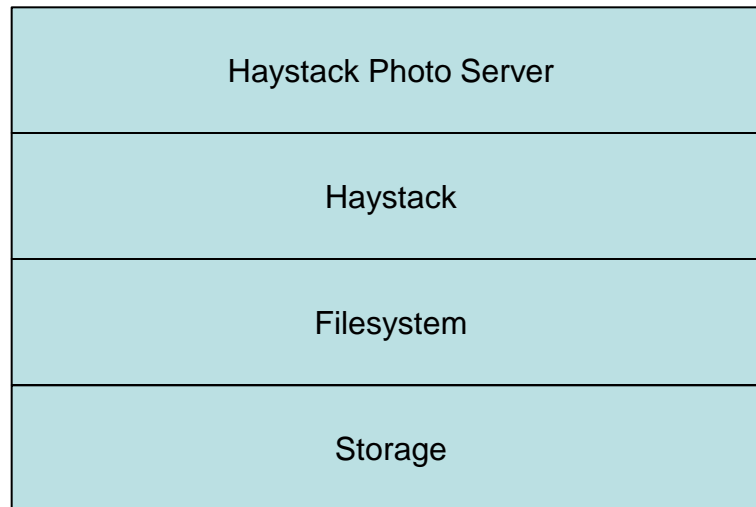
- Metadata bottleneck
 - Each image stored as a file
 - Large metadata size severely limits the metadata hit ratio
- Image read performance
 - ~10 iops / image read (large directories - thousands of files)
 - ~3 iops / image read (smaller directories - hundreds of files)
 - ~2.5 iops / image read (file handle cache)

Haystack based Design





Haystack Store

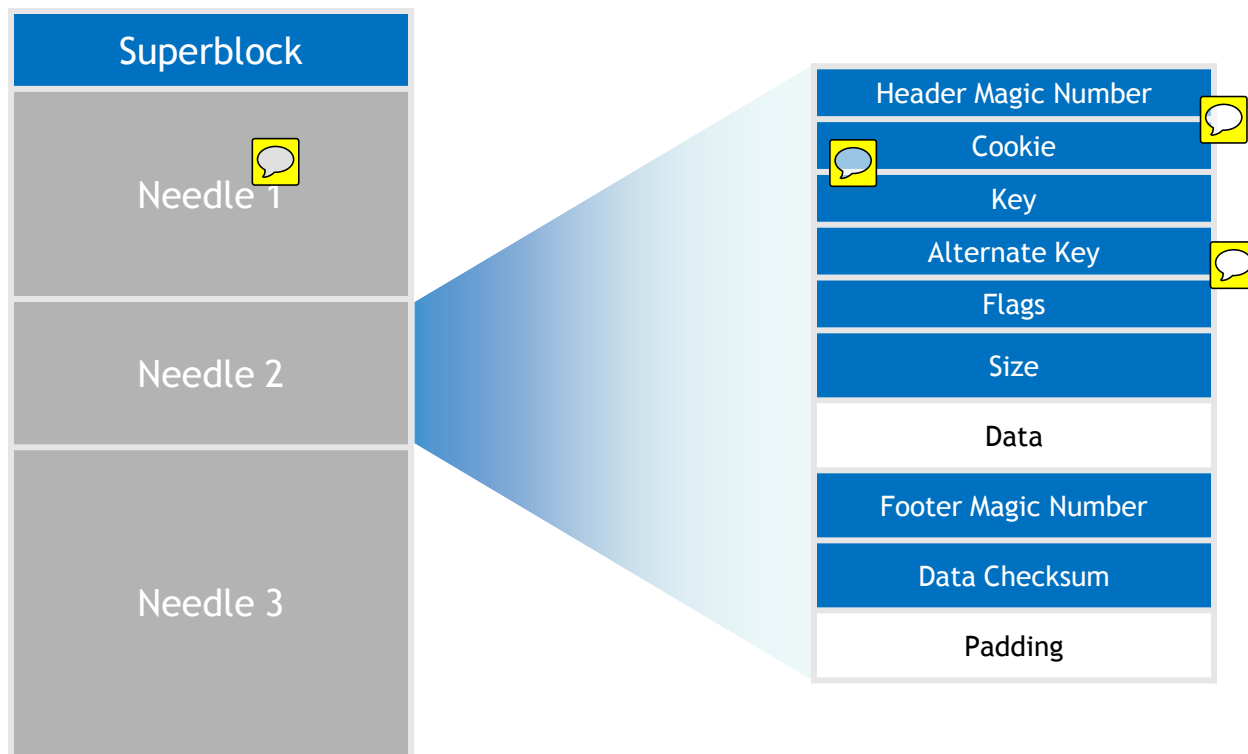
- Replaces Storage and Photo Server in NFS based Design



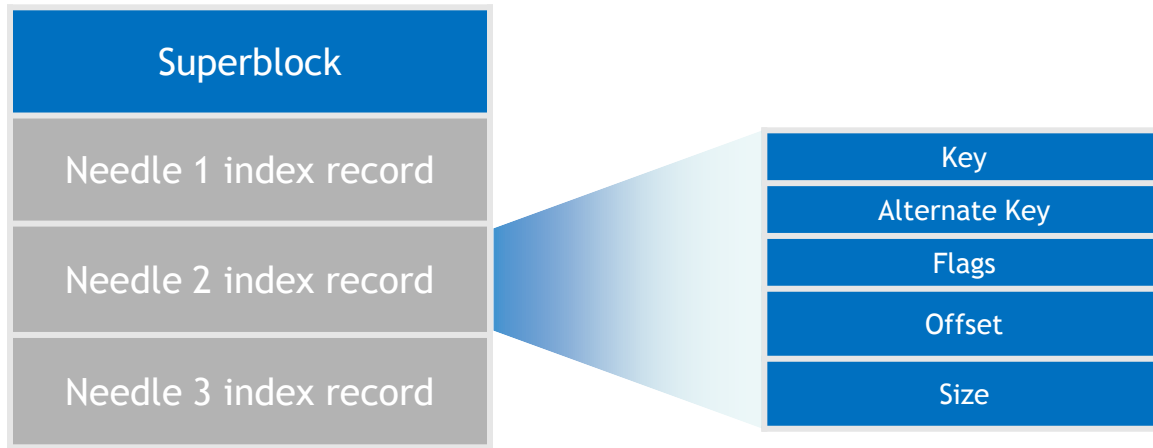
Haystack Store

- Storage
 - 12x 1TB SATA, RAID6
- Filesystem 
 - Single ~10TB xfs filesystem
- Haystack
 - Log structured, append only object store containing needles as object abstractions
 - 100 haystacks  per node each 100GB in size

Haystack Store - Haystack file Layout



Haystack Store - Haystack Index File Layout



Haystack Store - Photo Server

- Accepts HTTP requests and translates them to corresponding Haystack operations
- Builds and maintains an incore index of all images in the Haystack
- 32 bytes per photo (8 bytes per image vs. ~600 bytes per inode)
- ~5GB index / 10TB of images



64-bit photo key
1 st scaled image 32-bit offset / 16-bit size
2 nd scaled image 32-bit offset / 16-bit size
3 rd scaled image 32-bit offset / 16-bit size
4 th scaled image 32-bit offset / 16-bit size

Haystack Store Operations

- Read

- Lookup offset / size of the image in the incore index
- Read data (~1 iop)

- Multiwrite (Modify)

- Asynchronously append images one by one to the haystack file 
- Flush haystack file
- Asynchronously append index records to the index file 
- Flush index file if too many dirty index records
- Update incore index

Haystack Store Operations

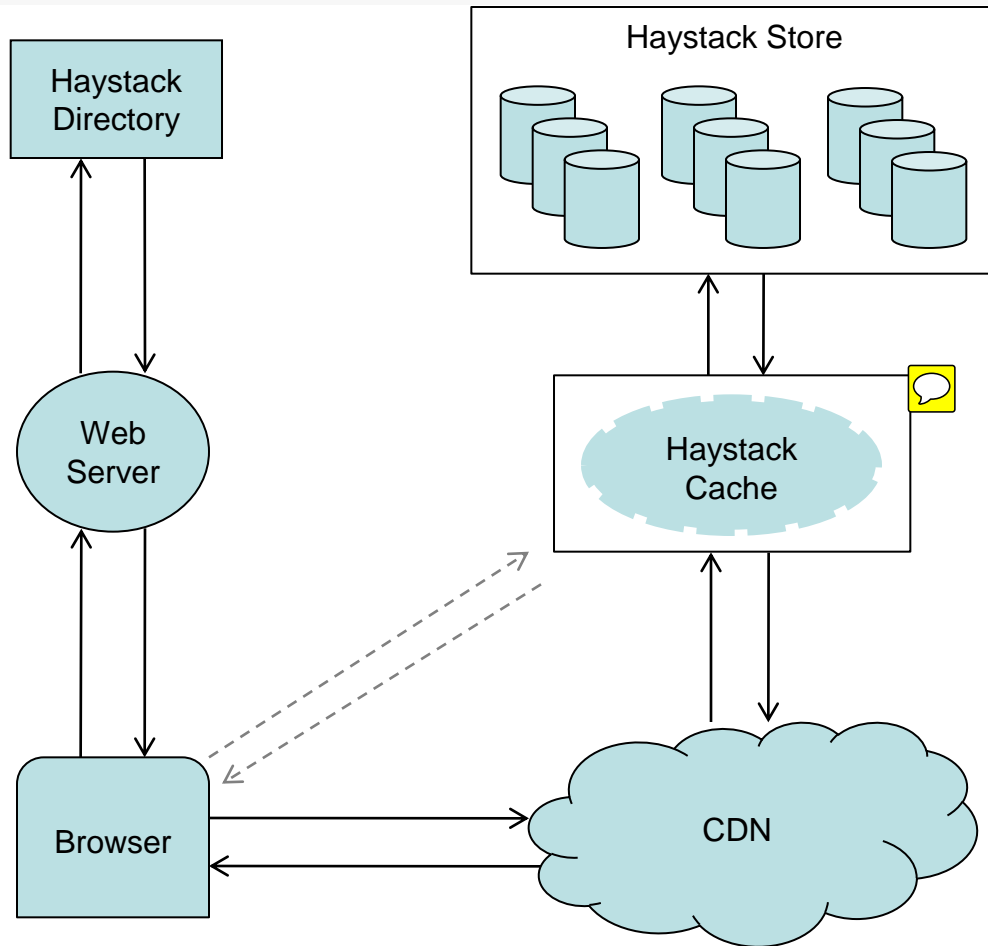
- Delete

- Lookup offset of the image in the incore index
- Synchronously mark image as “DELETED” in the needle header
- Update incore index

- Compaction

- Infrequent  online operation
- Create a copy of haystack skipping duplicates and deleted photos

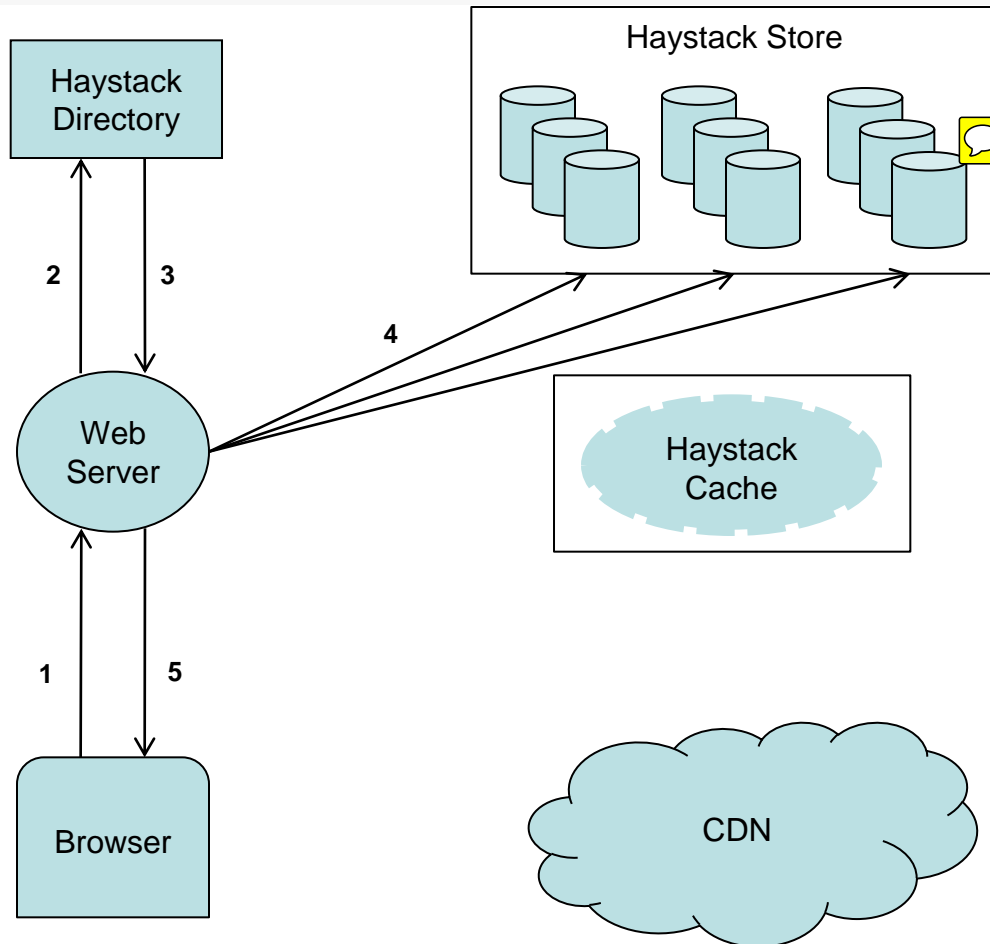
Haystack based Design



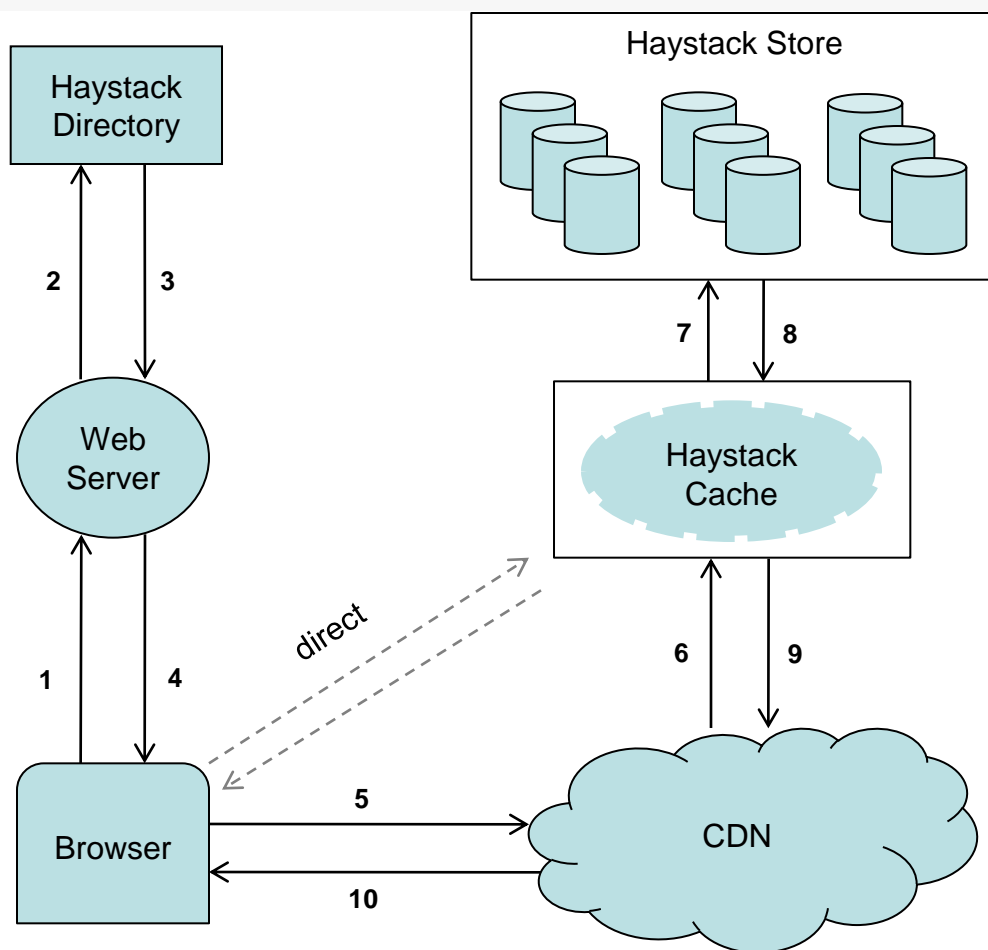
Haystack Directory

- Logical to physical volume mapping
 - 3 physical haystacks (on 3 nodes) per one logical volume
- URL generation
 - `http://<CDN>/<Cache>/<Node>/<Logical volume id, Image id>`
- Load Balancing
 - Writes across logical volumes
 - Reads across physical haystacks
- Caching strategy
 - External CDN or Local cache?

Haystack based Design - Photo Upload



Haystack based Design - Photo Download



Conclusion

- Haystack - simple and effective storage system
 - Optimized for random reads (~1 I/O per object read)
 - Cheap commodity storage
 - 8,500 LOC (C++)
 - 2 engineers 4 months from inception to initial deployment
- Future work
 - Software RAID6
 - Limit dependency on external CDN
 - Index on flash

Q&A

- Thanks!