

Agenda

1. Challenges at Scale

support@scaler.com

2. Case Study - del.icio.us

Pragy

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3. What & Why of HLD

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Prerequisite

Data Structures

Networking

Algorithms

Memory Mgmt

Databases

Concurrency

Schema Design

40-50% of understanding of solutions ✓ good!!

Focus → Problems



How we usually make applications

Teach programming : dummy / toy problems
Code → on their own laptop
Solution

- Real life :
- ① work with others (100+ engineers)
 - ② Terabytes of data (even more)
 - ③ Test
 - ④ Deploy (on multiple machines)
 - ⑤ Changing Requirements



Is life really that simple?

Real life poses a lot of challenges



The Google question

Staff Engineer

710 yrs at a tier-1 company
1-2 Cr per annum (India → Bangalore, Hyderabad, Chennai)

given a list of strings, sort them alphabetically.

Python

`strs.sort()`

Java

`Arrays.sort(strs)`

C++

`std::sort(strs.begin(),
 strs.end())`

Catch : there is 50 PB of data

1 bit → 0/1 fundamental unit of information

4 bits ⇒ nibble

8 bits ⇒ byte

Kilo ⇒ SI prefix
= 1000

1000 bytes ⇒ KB (Kilobyte)

$$2^{10} = 1024$$

10^6 bytes ⇒ MB (mega = million)

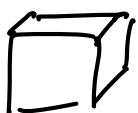
1024 bytes = Kibibyte
KiB

10^9 bytes ⇒ GB

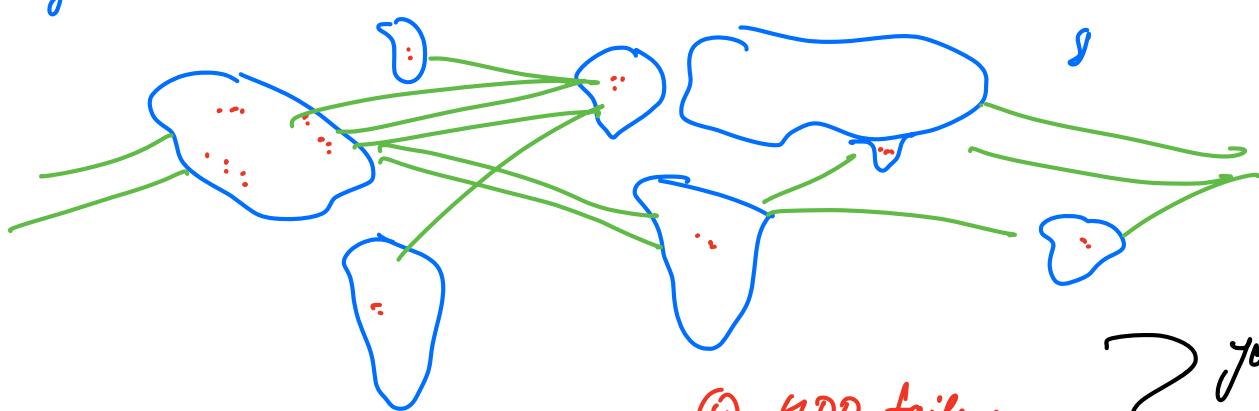
10^{12} bytes ⇒ TB

we have to send 50,000,000 GB of data

Can this data fit in RAM X NO
" " " " HDD X NO

 1000 laptops X NO

large data is distributed across the world



- ① Internet can go down
- ② Natural disasters
- ③ Machines can crash

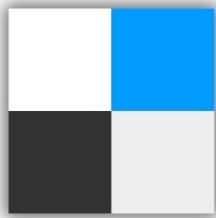
- ④ HDD failure
- ⑤ People error
- ⑥ Cyber Attacks
- ⑦ Electricity outage

} you need to
sort the strings

Moral

v. simple tasks become v. complex at Scale!!

High Level Design / System Architecture



Del.icio.us Case Study

Simple bookmarking service (Joshua)

- ? Launched in



2003



2005



2008



2009

2006

25,000 RS

128 Mb RAM

2.2GHz Con 2 Duo Pentium
CPU

40GB HDD

Dial-up internet 8Kbps

Motivation

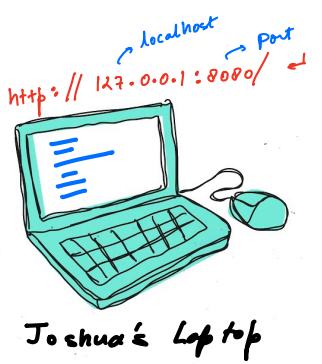


Proof of concept

Features

POC / MVP → usable
Minimal Viable Product
↳ briefly

1. Identify user → Login user-id
2. Add Bookmark user-id, URL
3. Fetch My Bookmarks user-id

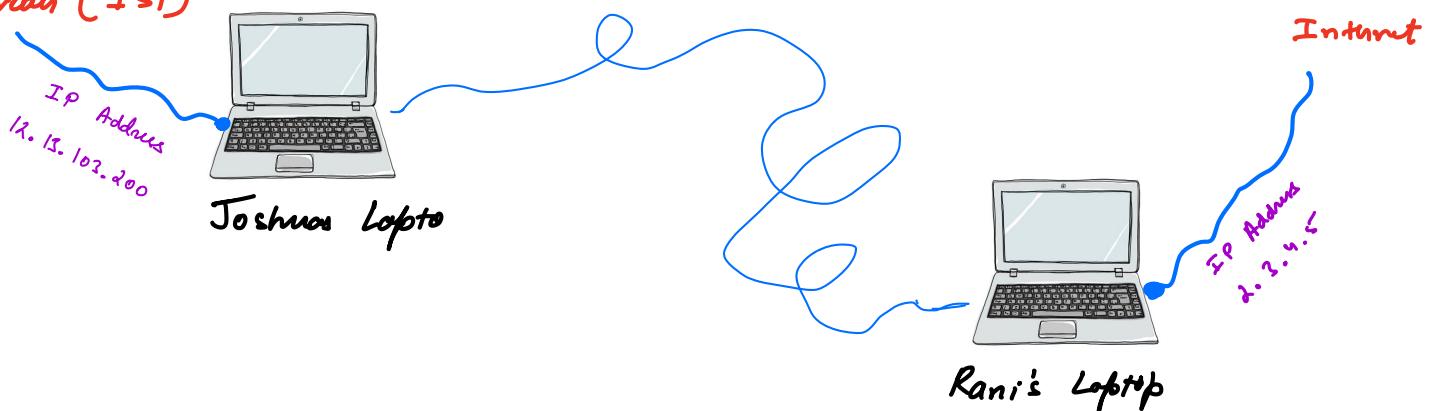


to be continued..



Fantastic websites & where to find them

Internet Service
Providers (ISP)



? Quiz

mostly any person will use the domain

① enter IP Address 12.12.102.200

② enter domain ://delicious/

Domain Name Service (DNS)

0.8 world pop

≤ 5 B have internet ⇒ ≤ 1 trillion devices on internet!

Joshua



Rani



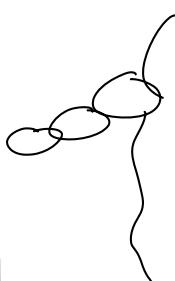
Achyut



Monika



ICANN



Domain	IP Address
scaln.com	— · — · —
delicious	12.12.102.200
google.com	— · — · —

Single Point of Failure

ICANN crash ⇒ Global Internet down

⚠ ICANN → I Can't!!

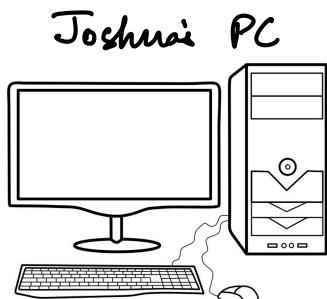
Del.icio.us

continued..

2003

2006

System Configuration



RAM	128 MB
Disk	40 GB
CPU	2.3 GHz 2 core

}

35,000 Rs



User-bookmarks

user-id	URL
1	scalar.com
2	google.com
2	cricinfo.buzz
1	jnuoଡ଼ିଆ.com

64 bit integer
(8 bytes)

1000 char
↓
1B/char
(1000 bytes)

≈ 1 KB / row

Gangan Style
view count (-ve)
32 bit Signed int
[-2³¹... 2³¹-1]
≈ -2 Billion -- 2 Billion



Quiz

S_{ip} : 10^3 B → 1 bookmark

#_g Bookmarks → 1 million row / day

$$\begin{aligned} \text{amount of data} &\Rightarrow \frac{1 \text{ KB}}{\text{row}} * \frac{10^6 \text{ row}}{\text{day}} \Rightarrow \frac{10^9 \text{ byte}}{\text{day}} \\ &= 1 \text{ GB / day} \end{aligned}$$

$$\begin{aligned} a^b \cdot a^c &\Rightarrow a^{b+c} \\ 10^3 \cdot 10^6 &\Rightarrow 10^{3+6} \\ &= 10^9 \end{aligned}$$



Quiz

$$\text{rate} = \frac{1 \text{ GB}}{\text{day}}$$

$$\text{time} = \frac{40 \text{ GB}}{1 \text{ GB/day}} = 40 \text{ days}$$

$$\text{HDD} = 40 \text{ GB}$$

$< 40 \text{ days} \therefore \text{OS/Driver/Code/...}$

Run out of space \rightarrow Service down



Solutions

1.

Vertical Scaling

buy more expensive A powerful hardware

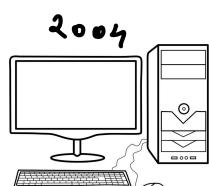


Joshua's Current Laptop

25,000 Rs

40GB HDD
128MB RAM
2 core CPU

more data



Gaming Laptop

2,00,000 Rs

80 GB HDD
256 MB RAM
2 core CPU

40GB of free space

$\approx 30 \text{ mon days}$



IBM Server Grade H/w

20,00,000 Rs

500 GB HDD
1 GB RAM
4 core CPU

$\approx 1.5 \text{ year}$



Custom build Mainframe/
Supercomputer

1 Crore Rs

2 TB HDD
10 GB RAM
20 core CPU

few mon years

2. Horizontal Scaling

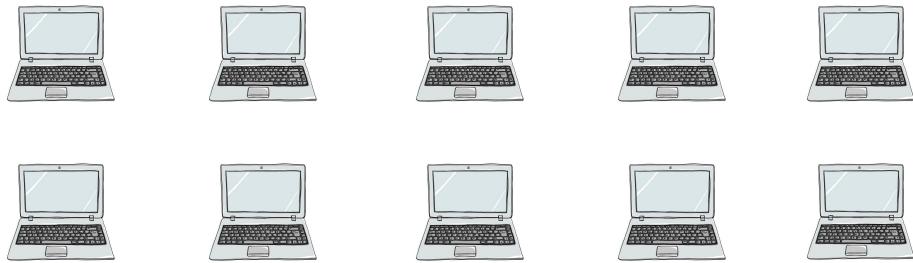
much more cost effective

buy lots of cheap hardware



$\frac{1,00,00,000}{35,000}$ laptops

≈ 285 laptops



Effective config

11 TB	HDD
26 GB	RAM
570 core	CPU

→ CPU bound tasks

Vertical

→ I/O bound tasks

Horizontal ✓

v. simple → throw money

v.v. difficult to manage → think
entire HLD is ∵ we will use
horizontal scaling

initially always try this
has limits

eventually you will definitely
need this!
unlimited

limited by today's tech

economy of scale!

movie rendering
Chat GPT ≈ 700GB
Stock exchange (NSE)

everything else

You will eventually run out of vertical scaling \therefore tech limits of today.

Typical Server Config

CPU 2-8 cores @ 2 GHz
RAM 2 - 22 GB
HDD 500 GB - 10 TB
N/W 10 Mbps - 1 Gbps

Max Server Config (13 Oct 2022)

CPU 600 cores @ 5 GHz
RAM 12 TB DDR5 @ 3200 MHz
HDD 2 PB
N/W 1 Tb/s

₹ 2 Million dollars

₹ 15 crore Rs

CPU \Rightarrow 300,000 cores

↳ Wafer Scale

↳ Cerebras

10:37 \rightarrow 10:50

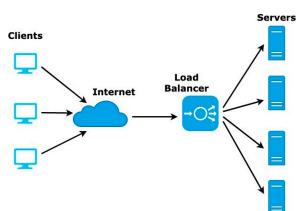
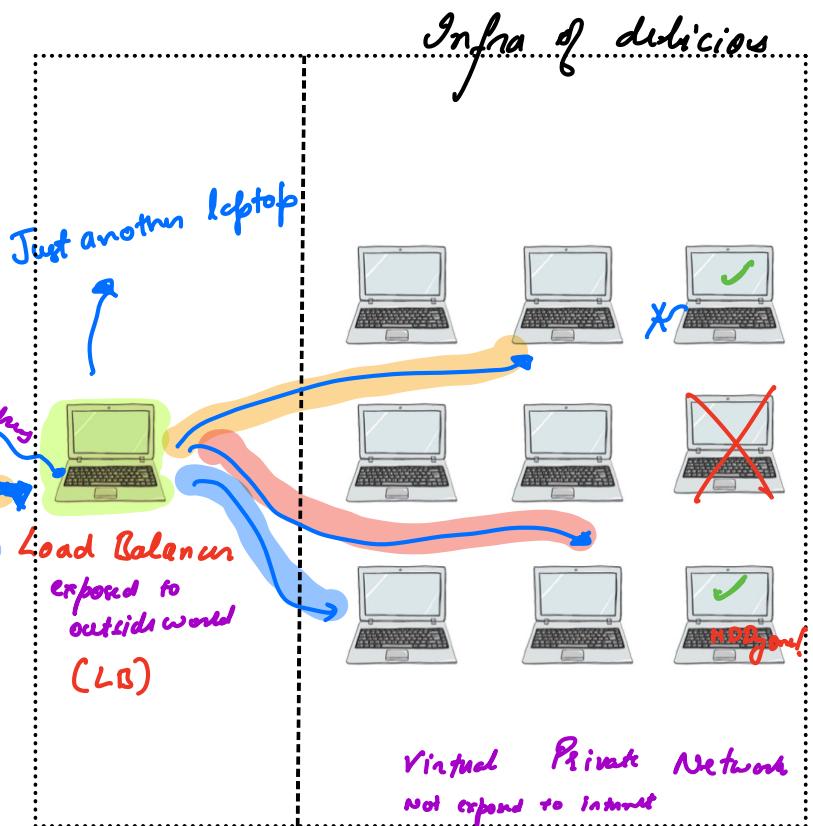
12 min

2.5 hours

9 pm \rightarrow 11:30 pm



Quiz



Load Balancing

Load Balancer does NOT handle any request
it routes requests to other servers

Load Balancer
API Gateway
Reverse Proxy

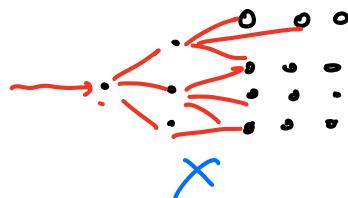
} diff but similar

nginx
Kong



Scaling Challenges

- ① what if LB crashes (failure mechanism)
- ② LB is spot + bottleneck (DNS)
- ③ How does LB know what servers are available? heartbeat / health check
- ④ Prevent data loss?



Sharding

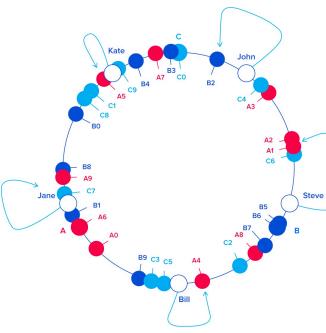
How to store the data?

Can all data fit on 1 laptop? X this was why we purchased more laptops in first place!

Data has to be partitioned & distributed across laptops

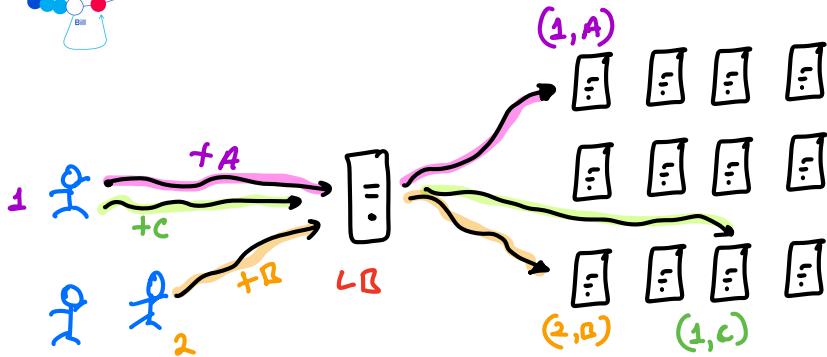
split up

which data goes where?



Where to find the data?

Consistent Hashing



Round-Robin Routing Policy



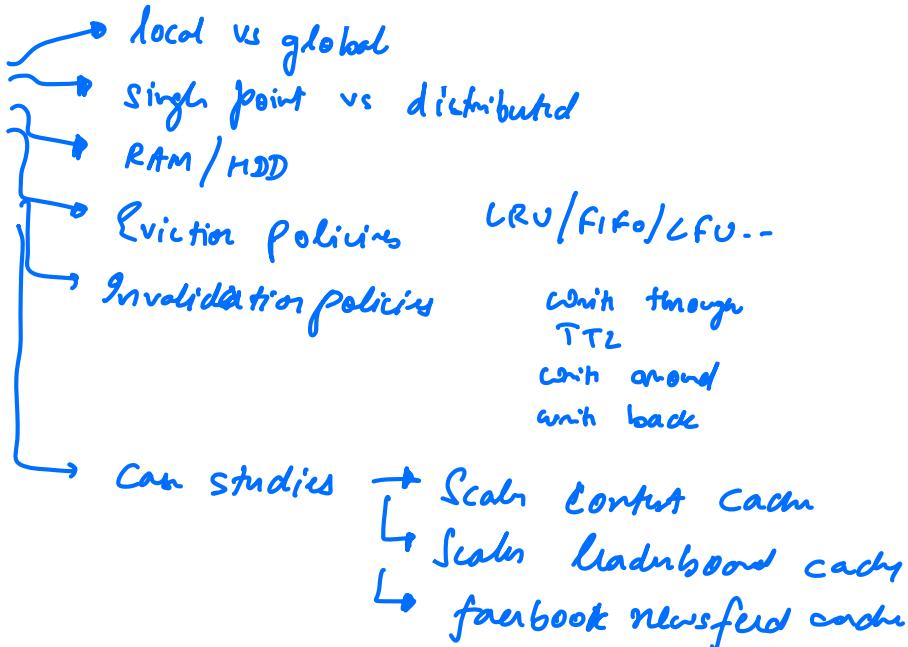
HLD Curriculum tentative

≈ 1.5 month module

What HLD is about

① Load Balancing / Consistent Hashing

② Caching



③ CAP / PACELC theor.

- Consistency vs eventual
- Under consistency
- Master-slave → Quorum

④ SQL vs NoSQL

- Key-value
- Col
- Doc
- file
- deep dive into Sharding
- internal store data (LSM Trees)
- db Orchestration

⑤ Case Studies

- ↳ Google Auto complete (Typeahead)
- ↳ Messaging (slack / fb / whatsapp)
- ↳ Elastic Search
- ↳ Ride Booking (Uber) → Quad Trees
- ↳ File Storage (Drive / S3)
- ↳ Video Streaming (Hulu / Netflix / Scales)

⑥ Messaging Queues - Kafka + Zookeeper

⑦ Microservices

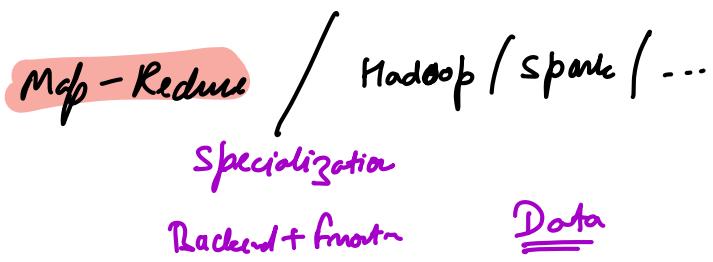
- ↳ Monolith vs Microservice
- ↳ Distributed Transactions
- ↳ Communication
- ↳ Dist Logging
- ↳ Saga
- ↳ Event Driven

⑧ Popular Interview Question.

What HLD is NOT about

- ① devops CI/CD (Project module)
- ② cloud
- ③ docker / k8s / tensorflow / --.

Practical part of
HLD
is Case Studies
architecture design



Software dev.

- fun/leg: ① Typists
AWS CCNA
② Technicians
Architect DSA
③ Thinkers.

requirements → code (language / framework)
experts in tools (Android dev / back / front / full)
solve problems