Big Data

Tuur Vanhoutte

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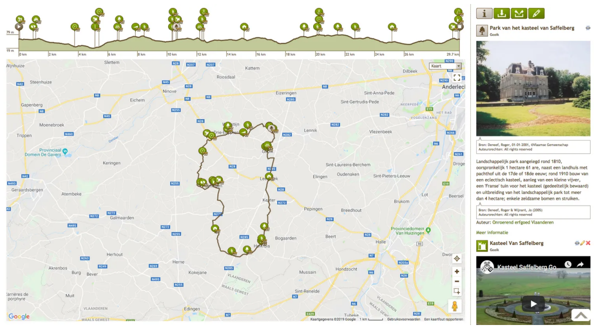
Inhoudsopgave

1 Understanding Data Intensive Applications

1.1 Why Big Data?

1.1.1 Use case: data intensive application RouteYou



Figuur 1: RouteYou

- Routes - user preferences & interests
- Searcheable Text data
- Geospatial data
- Community driven
  - Exponential user growth is necessary to make the application posssible
  - Server power/bills should grow linearly

1.2 Data Intensive Application: RAMS!

- **Reliable**
  - tolerating human mistakes
- **Available**
- **Maintainable**
  - Easy to adapt (evolvability)
  - Easy to deploy & operate (operations/sys admins)
- **Scalable**
  - User growth while maintaining low response times

1.2.1 Common similar abbreviations

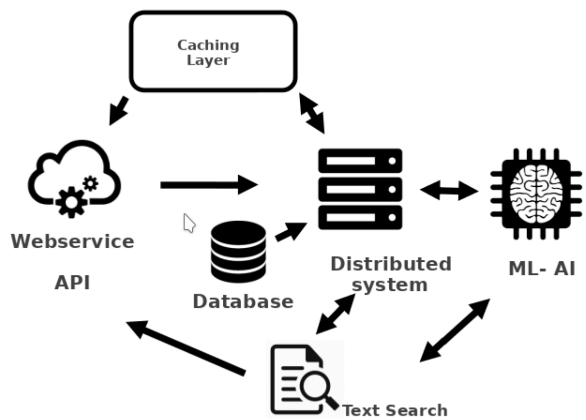
- Infrastructure: RAS (Reliable, Available, Serviceable)
- Developer: RMS (Reliable, Maintainable, Scalable)

1.2.2 Methods to improve Maintainability

- Github
- Error handling
- Relative paths (not absolute)
- Abstraction (REST API, . . .)
- Documentation

1.2.3 RAMS applied to RouteYou application

- Geospatial data (longitude, latitude)
- Available & scalable
- Scalable & low response time
- Community driven - unstructured text
- Maintainable: automatic classification of community input (ML)



Figuur 2: To support many users, you need a caching layer

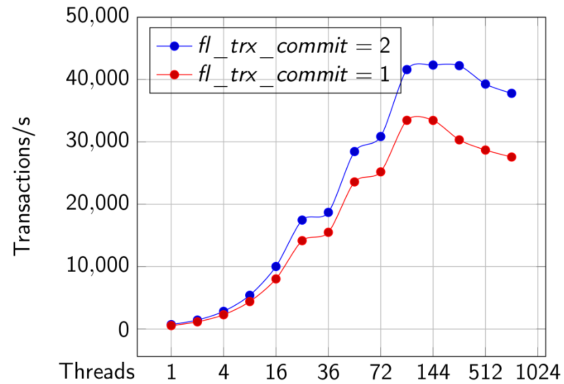
1.3 Learning outcome for this module

Being able to make infrastructure & software choices to build a Reliable, Available, Maintainable & Scalable (RAMS) data intensive application.

- Deep insights into database technology & cloud services
- Connecting with Machine Learning & AI
- Configuring a data back-end (in the cloud or locally)

1.4 Scaling

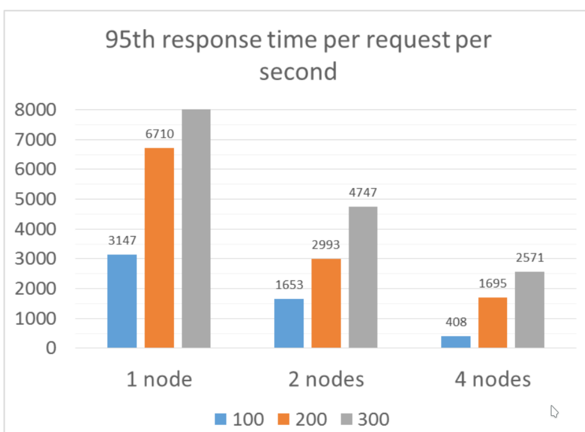
1.4.1 MySQL scaling



Figuur 3: Transactions/sec

- Processing power of 16-64 = slightly less then 4x
- Real performance: 2.3x
- = scaling up: add more processing power to the system

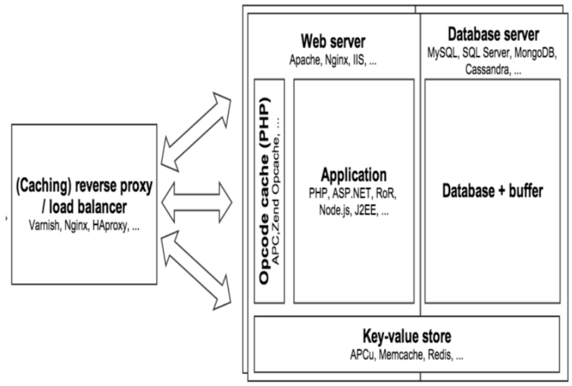
1.4.2 ElasticSearch Scaling: distributed system



Figuur 4: Response time per request

- Scaling out: add more servers to your data system

1.4.3 Professional architecture (Dev oriented)



Figuur 5: Professional architecture diagram

- **Reverse proxy / Load balancer:** improves scalability
- **Opcode/app/Webserver:** webservice + API
- **Key-value store:** 'caching layer'
- **Database server:** distributed storage system + relational database

1.4.4 Time series Distributed database (OpenTSDB, InfluxDB)

Location	DateTime	maxTemp	minTemp	prcp	dewpoint	gust	seaLevelPres	windSpeed
3927	2011-09-16T00:00:00	82	80.1	0	75.9		1015.9	5.9
3864	2011-09-16T00:00:00	82.4	71.6	0	70.2			4.2
3860	2011-09-16T00:00:00	86	75	0	68.7	22	1019	12
3858	2011-09-16T00:00:00	84	79	0	71.4		1018.5	4.9
3855	2011-09-16T00:00:00	84.9	78.1	0	70		1019.1	9.8
3853	2011-09-16T00:00:00	82	62.1	0	69.8	25.1	1014.9	12.5
3847	2011-09-16T00:00:00	87.1	78.1	0	56.6		1013	5.3
3846	2011-09-16T00:00:00	93.9	81	0	55.2		1006.4	2.9
3845	2011-09-16T00:00:00	91	78.1	0	62.4			3.3
3843	2011-09-16T00:00:00	59	52	0.05	39.2		1024.1	5.9
3837	2011-09-16T00:00:00	54	42.1	0.07	40.3	20	1017.7	5.3
3835	2011-09-16T00:00:00	57.9	53.1	0	40.9	28	1017.9	13.5
3833	2011-09-16T00:00:00	55.9	52	0.01	38.8	24.1	1019.5	14
3830	2011-09-16T00:00:00	57.2	48.9	0.04	42	20	1016.7	10.1
3827	2011-09-16T00:00:00	63	46.9	0	41.8	22	1010.8	13

Figuur 6: Data from windmill sensors. Most sensors log about every second

- Losing data is not that big a problem
- Massive amount of data to write

1.5 Scalability & application performance management

Response times and percentiles rule the web

1.5.1 The need for speed: some insights from Google

- Speed is a ranking factor
- When your site has high response times, less URLs will be crawled from your site
- 53% of visits are abandoned if a site takes longer than 3 seconds to load

- Slow websites will be labeled by Google Chrome

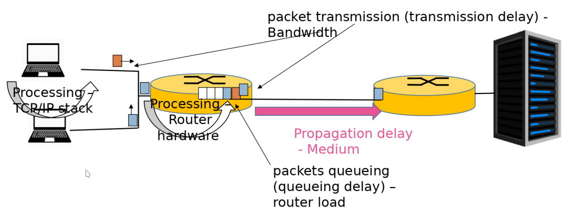
1.5.2 Response times for websites

- **Ideal:** "blink of an eyeïs 300-400 ms
- **Excellent:** 500ms to 1.5 seconds at most
- **Barely acceptable:** 3 seconds

Response time = Network latency + processing

- 2.9 seconds is faster than 50% of the web
- 1.7 seconds is faster than 75% of the web
- 0.8 seconds is faster than 94% of the web

1.5.3 4 components of network latency

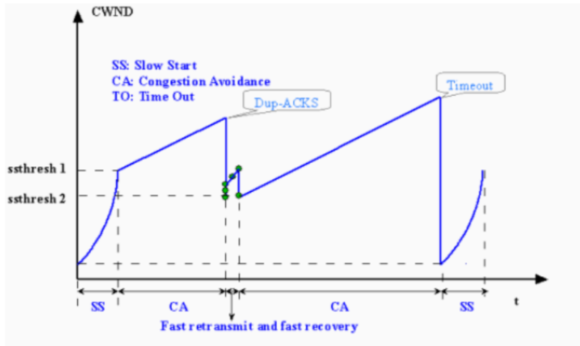


Figuur 7: Network latency diagram

- Processing delay
  - Processing network software stack (TCP/IP layers)
  - Routing decisions
- Transmission delay
  - Bits on physical link (Bandwidth plays a big role, ex: 1Gbit/s)
- Propagation delay
  - Speed of EM signals in fiber: 200.000 km/s (67% of lightspeed)
  - Changes with distance and medium (Copper: 64% of lightspeed)
- Queing delay
  - Time spent in router & NIC buffers

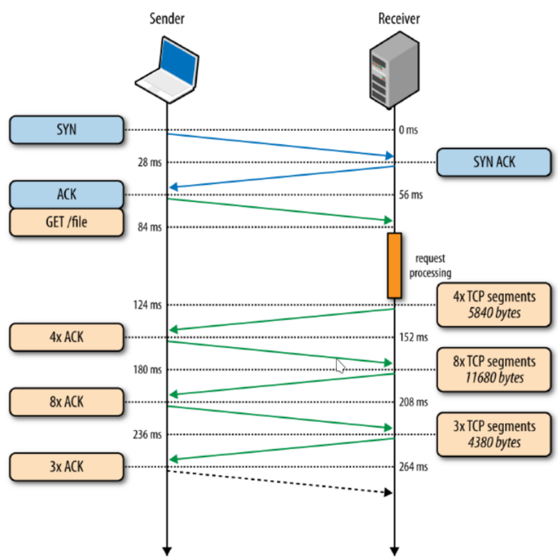
1.5.4 TCP Congestion Window - slow start

- Network congestion = a network node or link is carrying more data than it can handle
- The internet is built around dropped packages



Figuur 8: TCP Congestion window

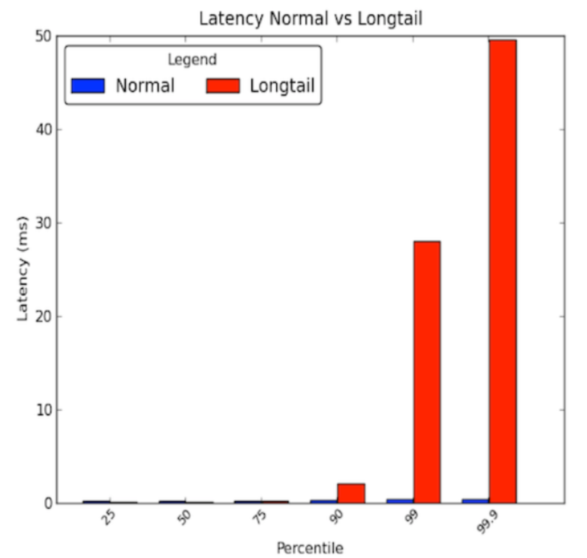
- 4-8-16-32 TCP segments (Win 2008, Win7)
- 10-20-40 (Linux 2.6+, Windows Server 2016 / Windows 10)



Figuur 9: Because of many handshakes, there is a lot of latency

- Solution: KeepAlive of a HTTP Persistent Connection
  - Only one 3-way handshake for many requests
  - Lower network & CPU load
  - Lower response times
  - **Downside**: more connections open ⇒ more memory, more connection failures, app crashing, ...
- Measure parallel requests of a website using `https://www.webpagetest.org/`
- Get a waterfall view of a webpage

1.5.5 Long tail latency



Figuur 10: Long tail latency vs Normal latency

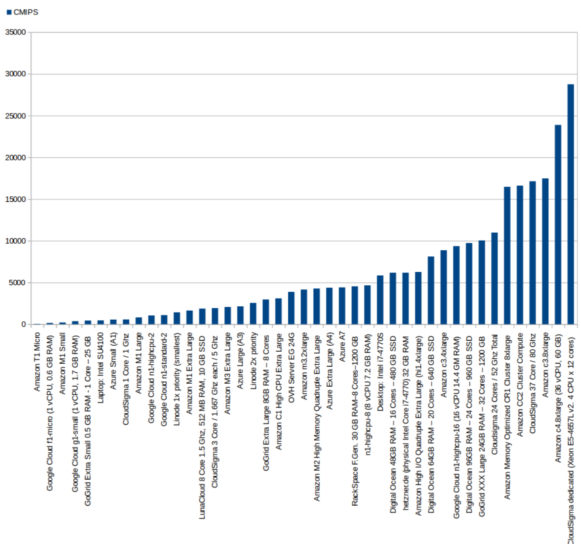
- Average = useless
- Long tail latency = 99th percentile
  - To be experienced by a lot more than 1% of users!
- Best customers encounter highest percentiles
- URL consists of many requests

1.6 Conclusion

- Our goal is RAMS (or RASS)
- Many data models & stores: transactional, timeseries, text search
- Website 99th percentile + DNS + TCP ⇒ < 2s response time
  - Efficient caching
  - Think about your architecture (infrastructure + software) before coding

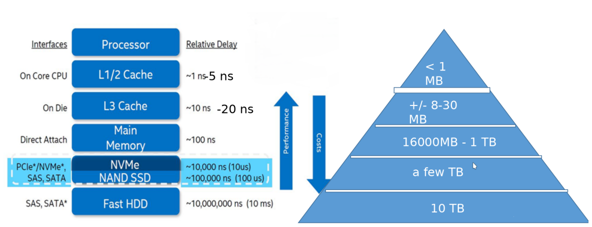
2 Professional storage

2.1 Cloud MIPS



Figuur 11: MIPS = Million Instructions Per Second

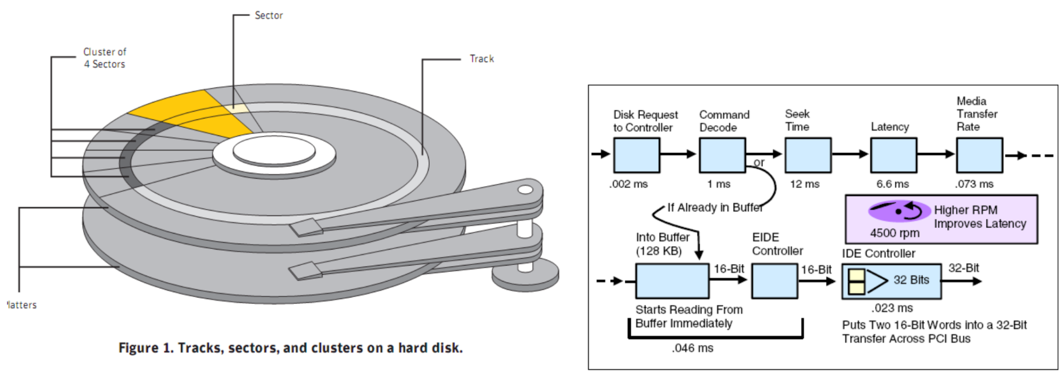
2.2 Latency vs storage space pyramid



Figuur 12: The higher the performance, the higher the cost per byte of storage

2.3 Storage media

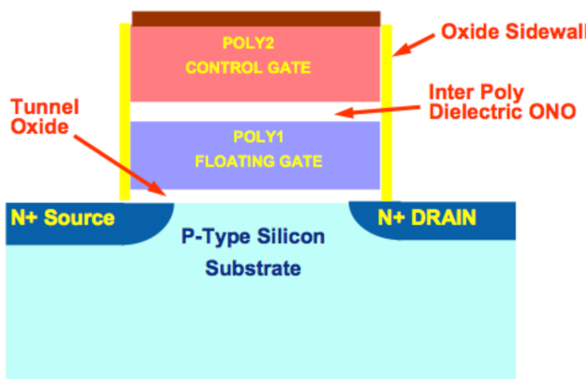
2.3.1 Magnetic disks



Figuur 13: Massive capacity but mechanical latency

- Seek time and latency are the key bottlenecks
- Need large quantity of disks for good server performance

2.3.2 Flash (NAND) / SSDs



Figuur 14: Flash storage

- NAND = MOSFET + floating gate
- Voltage between control gate and N+ : electrons in floating gate
- This works very quickly

2.3.3 Big difference between read and writing

	MLC NAND flash
Random Read (page)	50-100 µs
Erase (block)	1000-2000 µs per block
Programming (page)	40-250 µs

Figuur 15

- Limited number of writes
- Slow block write
- Limited "normal"write (programming)

2.3.4 IOPS vs Bandwidth

- Transactions & virtualized workloads: lots of random access
- Timeseries fileserving: mostly sequential
- HDD: random performance can be extremely low to medium
- IOPS = Input/Output Operations Per Second

Storage device	Seagate Enterprise HDD	Intel SSD NVMe
	ST8000NE0001	DC3700
Capacity	8 TB	800 GB
Spindle speed (rpm)	7200	N/A
Max. BW (MB/s)	**230**	**600**
Latency (ms)	4,16	N/A
Seek time	8	N/A
Total Random read time ms	12	0,08
Random Performance	1000 Random 4 KB blocks	1000 Random 4 KB blocks
Total Random read time (ms)	12000	80
Transfer time (ms)	17,4	6,7
Sustained Transfer rate (MB/s)	**0,33**	**46,15**
IOPS	83	11538
Sequential Performance	1x 4 MB block	1x 4 MB block
Total Random read time (ms)	12	0,08
Transfer time (ms)	17	7
Sustained Transfer rate (MB/s)	**136**	**593**

Figuur 16: An enterprise HDD vs an NVME SSD

2.3.5 Storage options

	Media Type	Interface	Read Latency (µs)	Write latency (µs)	Random IOPS	BW (MB/s)
HDD	Magnetic	SATA	10.000	10.000	100	1-200
Low-end SSD	NAND Flash	SATA	100-300+	40-2000+	5k-20k	100-550
High-end SSD	NAND Flash	NVMe	100-200+	20-1000+	50-200k	100-1800
3D-Xpoint	Electric resistance	NVMe	10-40	10-60	500+k	200-2000

Figuur 17: Storage options

Type	Queue depth	Random?	Write vs Read	Perf consistency
HDD	As low as possible (1-2)	Sequential! Random as low as 50 IOPS	Write slightly slower	Terrible (1 -200 MB/s)
Low-end SSD	8-16	Random	Write can be a lot slower	IOPS writes can vary 2-4x
High-end SSD	16+	Both	Write can be a lot slower	IOPS writes can vary 10-30 percent
3D-Xpoint	2+	Both	Does not matter	Very good

Figuur 18: Performance Conditions

2.4 Professional Storage Topology