Scalability in Semantic Data Management

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Forewarning

- Scalability
  - Multifaceted, extremely challenging issue
    - ongoing efforts for much simpler data models than SW models
  - *Critical* for large-scale problems
    - LOD / Enterprise data

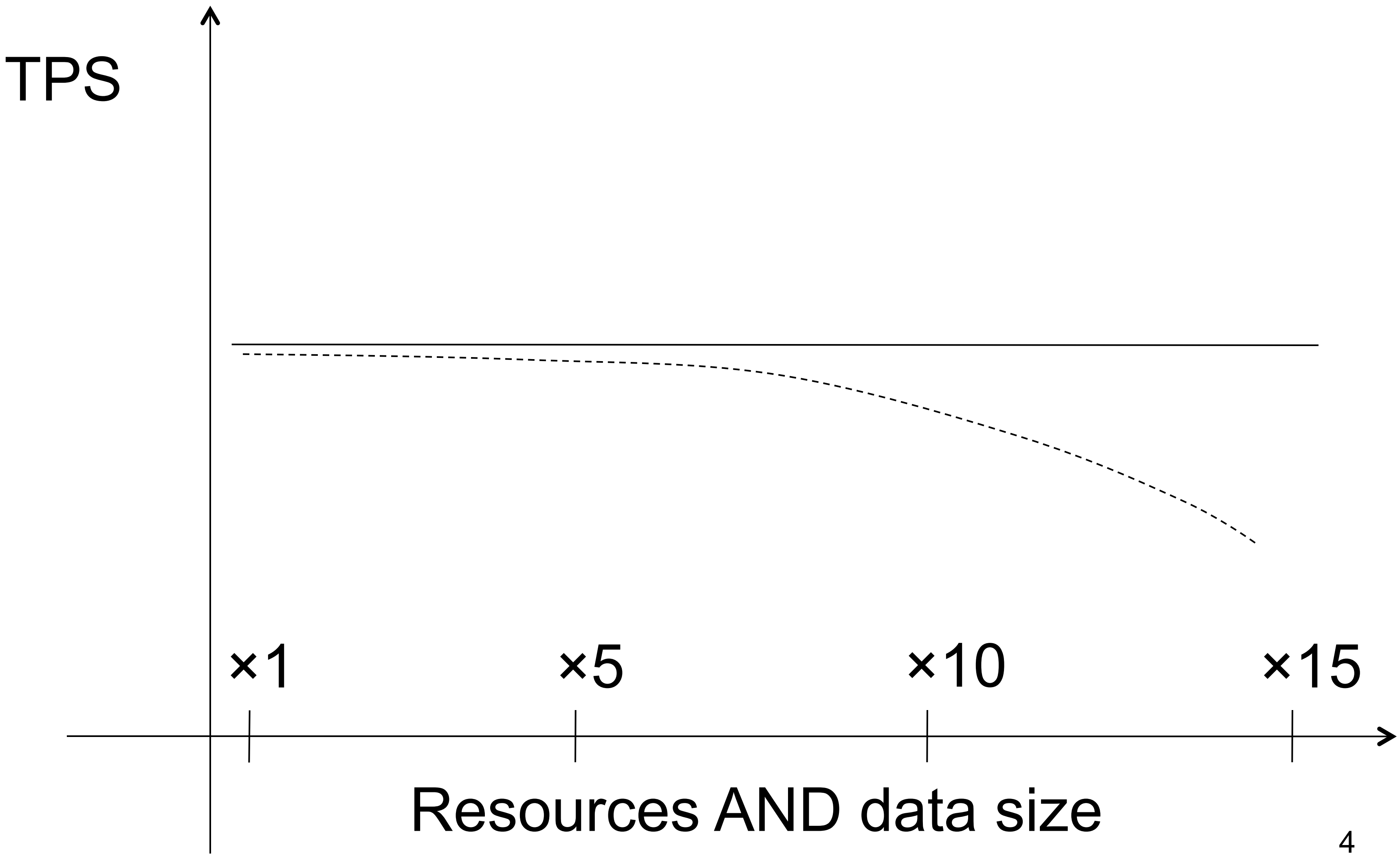
- Tutorial?
  - One (simplified) story

- Bias ahead towards
  - My background (Decentralized P2P & OSDNFA DB *systems*)
  - The metrics and problems I am interested in (e.g., TPS for complex queries on massive graphs)

Scalability

- [Wikipedia] “scalability is the ability of a system, network, or process, to handle growing amount of work in a capable manner or its ability to be enlarged to accommodate that growth.”

Linear v.s. Non-linear Scaleup



Scale up VS scale out

- Scale up
  - Vertical scaling
  - Add resources to a single node or system

- Scale out
  - Horizontal scaling
  - Add more nodes to the system

Scaling Up SW Systems

- Throwing resources at a problem is only effective when addressing the bottleneck of the system
  - CPU-bound contexts
  - IO-bound contexts (disk / network-bound)

  $\Rightarrow$Better CPU $\neq$ faster data processing

- Bottleneck depends on
  - System
  - Hardware
  - Workload

Shifting Bottlenecks

- Bottlenecks are thus not always application-dependent
  - Advances, CPU/disk tradeoffs
  - Ex.: complex analytics used to be disk-bound on legacy RDMBSs, but Vertica is often CPU-bound

⇒Importance of (good) benchmarking

⇒Various benchmarks

⇒Benchmarking platforms

Scaling-up Disk-bound SW Systems

- Disk is often the bottleneck because of
  - Slow buffered reads (e.g., 50MB/s)
  - *Slower than slow* random reads (seek = 10ms)

- (At least) four ways of scaling the issue
  - Read less (e.g., compress, index, cache)
  - Jump less (e.g., co-locate)
  - Buy new disks
  - Climb up the memory hierarchy
    - Study Flash / PCM / Main-memory characteristics

Recycling Old Technology

- Typically yields suboptimal results (unless the context has not changed)
  - N-ary storage: very verbose
  - B-trees: often require many seeks
  - Relational model: implies many self-joins

A few SW examples

- Native indexing: Hexastore [Weiss08]
- Native indexing + compression and a bunch of neat tricks: RDF-3x [Neumann08]
- Co-location + compression: Vertical SW-Store [Abadi07]
- Co-location, co-location, co-location: dipLODocus[RDF] [Wylot11]
- Further examples?

What about Main-Memory Systems?

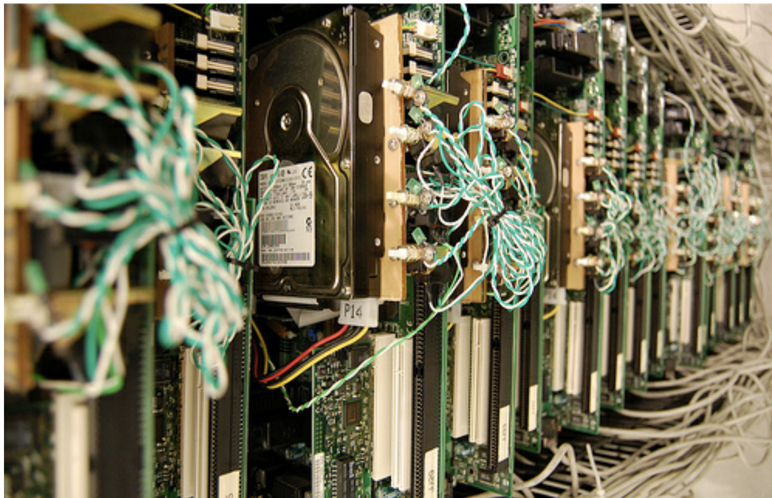
- (Hyrise system [Grund10]) Distinction between
  - Layout-independent operations (e.g., mathematical operations)
  - Layout-dependent operations (e.g., reads, writes…)

- Layout-independent operations
  - New physical operators, algorithms
  - Multi-core optimizations

- Layout-dependent operations
  - Cache locality!
  - Many of the techniques from the previous slide can apply

Scaling out SW Systems

- Historically, three architectures of parallel DBMSs
  - Shared Memory
  - Shared Disk
  - Shared Nothing
- Expensive to scale shared memory / disks systems
- Shared nothing is prevalent today
  - Clusters of commodity machines (Google, Hadoop, AWS, SciDB...)
    - Simply add boxes / racks
    - Failure is the norm
  - Also the most complex to design…

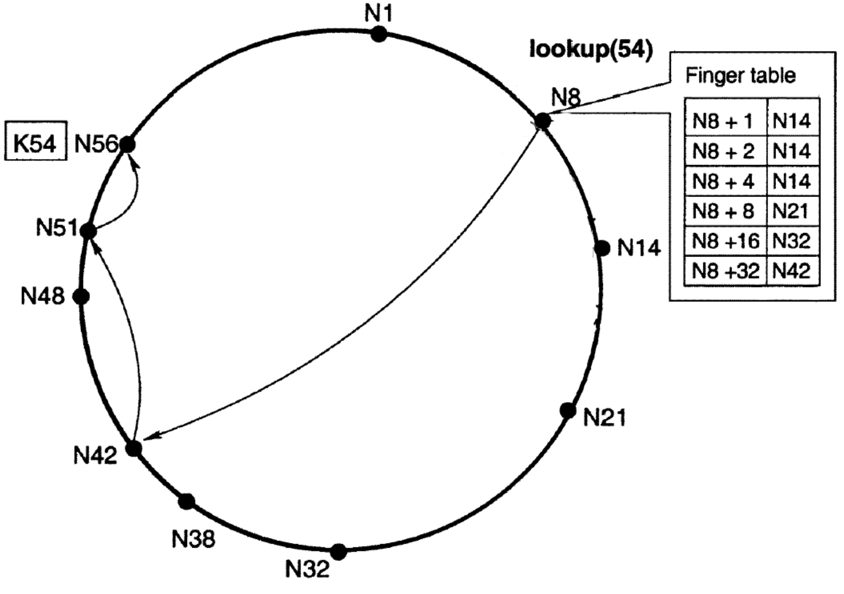


Contrasted Scenarii

- Typical high-throughput, read-write OLTP workloads
  - Load-balancing, inter-query parallelism
  - Functional redundancy
  - Logging, consistency (CAP)
- Typical complex analytic workloads
  - Intra-operator parallelism
  - Amdahl's law
  - Data-to-node affinity
- Current and future workloads for SW systems?
  - From read-mostly to read-write Web?

Typical SW Scale-out

- GridVine (hash-partitioning) [Aberer04]
  - Index subject, predicate and object in a distributed identifier space
  - Queries are resolved using iterative, distributed look-ups + joins
  - GridVine based on a DHT; now alternate (better?) substrates
    - Key-value stores
    - Hadoop
    - Others?



Example of Query Resolution

– Select ?s Where {
  ?s is_a Student
  ?s lives_in Seattle
  ?s takes ?c
  ?c is_a GraduateCourse }

– $\pi_s\ \sigma_{p=\text{"is\_a"}\ \wedge\ o=\text{"Student"}}$
$\bowtie\ \pi_s\ \sigma_{p=\text{"lives\_in"}\ \wedge\ o=\text{"Seattle"}}$
$\bowtie\ \pi_s\ (\sigma_{p=\text{"takes"}}\ {}_{o}{\bowtie}_{s}\ \ \sigma_{p=\text{"is\_a"}\ \wedge\ o=\text{"GraduateCourse"}})$

Better Partitionings?

- Triple-table indexing requires one distributed look-up per triple pattern + join
- Often leads to poor intra-query parallelism

- Better (graph) partitionings?
  - Range partitioning?
  - K-Means? [Huang11]
  - Full graph decomposition? [Microsoft Horton]
  - RDF molecules? [dipLODocus]
  - Other examples?

Yet Another Problem worth Tackling

- Federated (LoD) queries
  - Collaborative queries involving independent nodes
  - Fairly new actually
    - Not your typical wrapper-mediator system
- Several interesting research directions for scalability
  - FedX [Schwarte2011]
    - Sesame + efficient distributed processing
  - Graph optimizations [Wang2011]
  - Collaborative *memcached*?
  - Further directions?

Other Scalability Aspects I Omitted

- SW Scalability w.r.t.
  - Reasoning
  - Search & ranking
  - Entity resolution
  - Data ingestion
  - Data cleaning
  - Data linking
  - Data provenance
  - Etc.

- Looking forward to discussing some of these this week

(Some) Conclusions

- SW Scalability is a multifaceted and challenging problem
  - *Essential* for many SW deployments
- Recycling old techniques often lead to sub-optimal solutions
  - Unless the context is similar
- Building dedicated platforms is generally-speaking a good idea
  - Requires a good understanding of hardware platform and workload
  - Benchmark and benchmarking infrastructures, e.g. BowlognaBench, http://oltpbenchmark.com

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