



# Implementing MGRID

CHAR(11), Cambridge, July 12, 2011

# Portavita

- Chronic disease management
- Largest online electronic health record (EHR) in Netherlands
- Largest telemedicine project in Europe

The screenshot shows a Firefox browser window displaying the 'Digital logbook' interface. The title bar includes the Firefox logo, menu items (Bestand, Bewerken, Beeld, Geschiedenis, Bladwijzers, Extra, Venster, Help), system icons (battery, signal, etc.), and the date/time (Fri 12:15). The address bar shows the URL [digitaallogboek.nl](https://www.demo.digitaallogboek.nl/transmuraal/index.html). The main content area is titled 'Digitaal Logboek' and 'PORTAVITA'. It features a sidebar with links for 'Self-management' (Diabetes diary, Enter CCQ, Enter MRC), 'Medical record' (Check-ups, Results, Indicators, Medication), and 'Personal' (Messages). The main content area displays a message about Portavita-only information being removed until logout, followed by a 'Home page of Betes, D'. Below this is a 'Messages' section showing 'No new messages'. The 'Scheduled check-ups' section lists 6 rows of scheduled appointments:

Type of check-up	Treatment	Scheduled by	From date (no later than)
Routine check-up (diabetes)	Diabetes	Buurtzorg	24-12-2010 (22-01-2011)
Self-check (diabetes)	Diabetes	Praktijk Portavita Demo	03-05-2011 (01-06-2011)
Dietary Advice	Asthma/COPD	Praktijk Portavita Demo	31-05-2011 (29-06-2011)
Dietary Advice	Diabetes	Praktijk Portavita Demo	31-05-2011 (29-06-2011)
Consultation of lung specialist	Asthma/COPD	Demo Ziekenhuis	03-06-2011 (02-07-2011)
Spirometry	Asthma/COPD	Praktijk Portavita Demo	12-09-2011 (11-10-2011)



# Portavita

Firefox Bestand Bewerken Beeld Geschiedenis Bladwijzers Extra Venster Help

Betes, D – Portavita transmural care

Betes, D – Portavita transmural ... + portavita.nl https://www.demo.portavita.nl/acts/careprovision/opvragen\_monitor/index.html?sel=da0041ec724250cb0dd5fd1ea102051: Google

Portavita Transmuraal Diabetes Demo - Praktijk Portavita Demo - portavita

home - back - Monitor 24-06-2011 12:13:35

ASTHMA/COPD Betes, D (ALT F12) | Female: 03-03-1933 | Diabetes treatment | Treating physician: Duiser, K | DM2 since 11-2001 | Insulin/Oral medication | Angiopathy | Pregnancy wish

DIABETES

Treatment

Monitor Treatment plan Medication Patient diary Work list

Examine

Risk inventory Annual check-up Routine check-up Foot examination Interim check-up Self-check Fundus image screening Dietary Advice Consultation spec. Laboratory test Index

EPD general

Overview Change patient data Message overview Import laboratory results HIS communication Journal

**Treatment** Problems/Complaints Lifestyle Phys.Exam. Laboratory Fundus Feet 24 hour blood pressure OZIS

**Diagnosis**  
Type 2 diabetes mellitus  
Risk factors:  
- Angiopathy: Angina pectoris, Cardiac failure, Cerebrovascular Accident (CVA)  
- Pregnancy wish

**Automatic treatment advice**  
**Simms category 1**  
carry out feet examination every 6 months

Change  
**Memo**  
verhaal van de patient

Consult/Add treatment policy

**Treatment policy**

Date	Practitioner	Source	Consideration
23-06-11			Bericht van Betes, D aan Praktijk Portavita Demo Onderwerp: Glucosecurve Graag jullie advies.
26-05-11	portavita	FE	
10-05-11	Nielen	AC	
03-05-11	Betes, D	SC	
18-03-11	portavita	RI	2004 blinde darm
09-03-11	portavita	IC	
08-03-11	portavita	AC	
08-03-11	portavita	FE	
01-03-11	portavita	RI	

**Medication**  
Oral blood glucose lowering medication + insulin several times a day

Start date	Name	Dose
28-01-2010	asparaginase injpoeder 10.000ie (coli) fl	1D2EH
04-02-2010	insuline glarginje injvlist 100e/ml fl 10ml	0-0-0-10EH
24-09-2010	paracet/ascorb 500/30mg pdr	3D2EH
04-03-2011	paracet/codein 500/10mg tab	4D1EH

**Treatment team**

# Portavita

Firefox Bestand Bewerken Beeld Geschiedenis Bladwijzers Extra Venster Help

Portavita transmural care

Portavita transmural care portavita.nl https://www.demo.portavita.nl/beheer\_rollen/beheer\_activiteiten\_per\_rol.html?sel=069f788efc16a7ea4e786a6bfcae6bc42d9 Google

Portavita Transmuraal Diabetes Demo - Praktijk Portavita Demo - portavita

home - back - Management of activities per role 24-06-2011 12:14:09

Select role	Activity	Request	Schedule	Approve schedule	Carry out	Enter	Approve input	Inspect
Administration		<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Administration of ophthalmology		<input type="checkbox"/>	<input type="checkbox"/>					
Pharmacist		<input type="checkbox"/>	<input type="checkbox"/>					
Assistant physician		<input type="checkbox"/>	<input type="checkbox"/>					
Cardiologist		<input type="checkbox"/>	<input type="checkbox"/>					
COPD assistant		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
CVRM assistant		<input type="checkbox"/>	<input type="checkbox"/>					
Diabetes assistant		<input type="checkbox"/>	<input type="checkbox"/>					
Diabetes nurse		<input type="checkbox"/>	<input type="checkbox"/>					
Dietician		<input type="checkbox"/>	<input type="checkbox"/>					
Medical receptionist		<input checked="" type="checkbox"/>	<input type="checkbox"/>					
Physiotherapist		<input checked="" type="checkbox"/>	<input type="checkbox"/>					
Geriatrician		<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>				
GPII		<input type="checkbox"/>	<input type="checkbox"/>					
General practitioner		<input type="checkbox"/>	<input type="checkbox"/>					
internist		<input checked="" type="checkbox"/>	<input type="checkbox"/>					
Lung specialist		<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>				
Pulmonary care nurse		<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>				
Nephrologist		<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>				
Ophthalmologist		<input type="checkbox"/>	<input type="checkbox"/>					
Podotherapist		<input type="checkbox"/>	<input type="checkbox"/>					
MAGP		<input type="checkbox"/>	<input type="checkbox"/>					
Practice assistant		<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>				
Consultant		<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>				
System administrator		<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>				
Activity	Request	Schedule	Approve schedule	Carry out	Enter	Approve input	Inspect	
Ankle-Arm Index	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>

# Portavita

Firefox Bestand Bewerken Beeld Geschiedenis Bladwijzers Extra Venster Help Portavita transmural care

Portavita transmural care portavita.nl https://www.demo.portavita.nl/acts/careprovision/opvragen\_management\_info/indicatoren.html?sel=de03ff6ef55c5fed2a90f Google

Portavita Transmuraal Diabetes Demo - Praktijk Portavita Demo - portavita

home - terug - Indicatoren Type 2 diabetes 24-06-2011 12:13:09

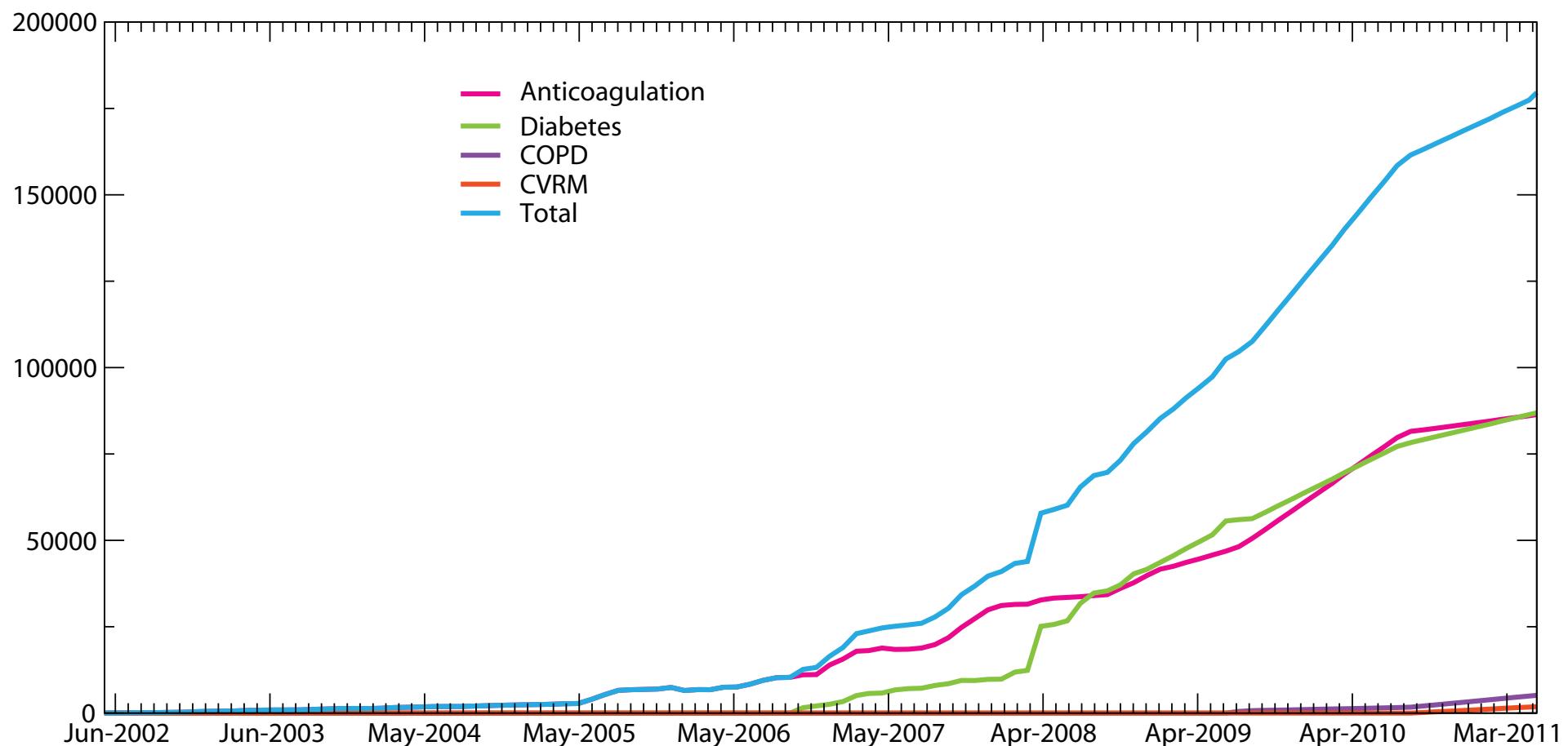
Show data based on knowledge of: 07-05-2011 Change

Type 2 diabetes Not type 2 diabetes

Data based on the knowledge of 07-05-2011 Parameter	All patients in health care group			Patients of Praktijk Portavita Demo			Patients of Boonekamp, FWM			Patients of Duister, K			Patients of portavita		
	Number	Percentage	Number	Percentage	Abnormality	Number	Percentage	Abnormality	Number	Percentage	Abnormality	Number	Percentage	Abnormality	
Total number of active patients	269	100%	7	2,6%		1	14,3%		5	71,4%		1	14,3%		
Patients with self-checks in last year	32	11,9%	1	14,3%	2%.	0	0,0%	-14%.	1	20,0%	6%.	0	0,0%	-14%.	
Blood pressure of patients measured last year	47	17,5%	2	28,6%	11%.	1	100,0%	71%.	1	20,0%	-9%.	0	0,0%	-29%.	
Of which patients with mean systolic blood pressure < 140	27	57,4%	2	100,0%	43%.	1	100,0%	0%.	1	100,0%	0%.	0	0,0%	-100%.	
Waarvan patiënten met gemiddelde syst 140 t/m 160	14	29,8%	0	0,0%	-30%.	0	0,0%	0%.	0	0,0%	0%.	0	0,0%	0%.	
Of which patients with mean systolic blood pressure > 160	6	12,8%	0	0,0%	-13%.	0	0,0%	0%.	0	0,0%	0%.	0	0,0%	0%.	
Of which patients with mean diastolic blood	16	34,0%	0	0,0%	-34%.	0	0,0%	0%.	0	0,0%	0%.	0	0,0%	0%.	

# Portavita's growth

Number of Patients NL

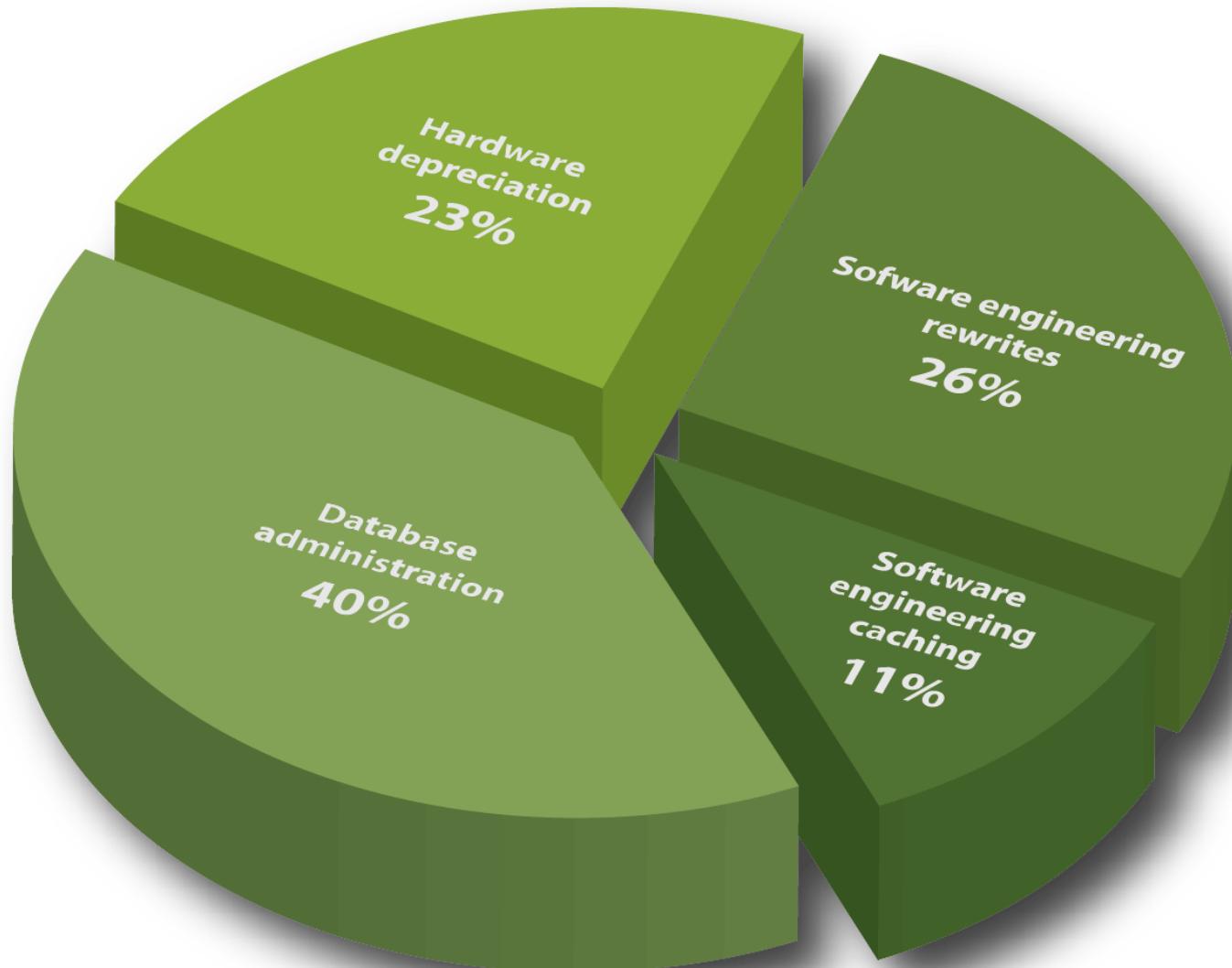


# Scaling up

- Several months orientation period, talked with VARs
- Took three months to implement



# Cost of scaling up



# Benefits of scaling out



- parallelize tuple streams for increased speed
- eliminate single server memory bandwidth, processor and IO bottlenecks
- control query latency with shard size
- machines can be each others replicas
- no negative economy of scale



# The MGRID Solution

- Make parallel PostgreSQL
  - that can scale out
  - that has built-in redundancy
  - that allows online adding of hardware
  - that supports all features of core PostgreSQL (ACID, stored procedures, etc)
- That supports medical data
  - ISO-21090 Healthcare Datatypes



# Healthcare Datatypes



# Physical Quantities: example

```
create table patient (name text, height pq, weight pq);
CREATE TABLE

insert into patient values
    ('Jack', '1.92 m', '92 kg')
,('Julia', '150 cm', '50 kg')
,('John', '188 cm', '84.3 kg')
,('Luke', '78 cm', '11800 g');
INSERT 0 4

create or replace function bmi(height pq, weight pq)
returns pq
as $$
    select convert($2, 'kg') / convert($1, 'm')^2;
$$ language sql immutable;
CREATE FUNCTION

select *, bmi(height, weight) from patient where height > '1.70 m'
order by weight;
   name | height | weight |          bmi
-----+-----+-----+
  John | 188 cm | 84.3 kg | 23.8512901765504753 kg/m2
  Jack | 1.92 m | 92 kg  | 24.9565972222222222 kg/m2
(2 rows)
```



# Physical Quantities: example

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create table patient (name text, height pq, weight pq);
CREATE TABLE

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(2 rows)

/* PQ contains most units used in science and engineering and can be used
 * outside the medical vertical. E.g. what is the mean travel time of light,
 * from the sun to the earth?
 */
select convert(pq '1 AU' / '[c]', 's');
      convert
-----
  499.0047838061356433 s
(1 row)
```



# Physical Quantities

- AdPQs used to document observations
- Based on Unified Code for Units of Measure
  - 294 units – a.o. units from SI, ISO 1000, ISO 2955, ANSI X3.50, CGS, unified U.S. & British Imperial units
- Operations supported:
  - Comparison: `<`, `>` and friends
  - Arithmetic: `+`, `-`, `/`, `*`, **power**
  - Aggregation: **min**, **max**, **avg**, **sum**, **var**, **stddev**
- Indexable

# Intervals and sets of point in time: example

```
select canonical(ivl_ts '[2004;2005[' + ivl_ts '[2005;2006[') as plus,
       canonical(ivl_ts '[2002;2010]' - ivl_ts '[2004;2005[') as minus;
plus      |      minus
-----+-----
[2004;2006[ | [2002;2004[;]2005;2010]
(1 row)

create table medication (name text, effectivetime ivl_ts);
insert into medication values ('Pete', '[20100316;20100514)'),
                               ('Pete', '[20100420;20100701'),
                               ('Pete', '[20101220;20110119'],
                               ('John', '[20100516;20100614'],
                               ('John', '[20100620;20100801'],
                               ('John', '[20101220;20110119');

INSERT 0 6

select * from medication where effectivetime @> '20100620';
 name |    effectivetime
-----+-----
 Pete | [20100420;20100701]
 John | [20100620;20100801]
(2 rows)

select name, canonical('2010' - sum(effectivetime)) as nomeds
  from medication group by name;
name |          nomeds
-----+-----
John | [20100101;20100516[;]20100614;20100620[;]20100801;20101220[
Pete | [20100101;20100316[;]20100701;20101220[
(2 rows)
```



# Coded values

- Controlled vocabularies in medical informatics
  - record information unambiguously
  - allow machine reasoning
- HL7v3 Coded value implementation
- Support for a large number of codesystems:
  - **S**ystemized **N**omenclature of **M**edicine – **C**linical **T**erms
  - HL7v3 vocabularies all Editions
  - **L**ogical **O**bserveration **I**dentifier **N**ames and **C**odes
  - you can add your own
- Supports
  - hierarchical code systems
  - code system versioning
- Indexable



# Coded values: example

```
select name, code(disorder), codesystemname(disorder),
       displayname(disorder) from observation;
 name | code      | codesystemname | displayname
-----+-----+-----+-----
 Willem | 71620000 | SNOMED-CT      | Fracture of femur
 Yeb    | 66308002 | SNOMED-CT      | Fracture of humerus
 Henk   | 262994004 | SNOMED-CT      | Leg sprain
(3 rows)
```

```
select name, displayname(disorder) from observation
where disorder << '284003005|Fracture of bone'::cv('SNOMED-CT');
 name | displayname
-----+
 Willem | Fracture of femur
 Yeb    | Fracture of humerus
(2 rows)
```

```
select name, displayname(disorder) from observation
where disorder << '127279002|Injury of lower extremity'::cv('SNOMED-CT');
 name | displayname
-----+
 Willem | Fracture of femur
 Henk   | Leg sprain
(2 rows)
```

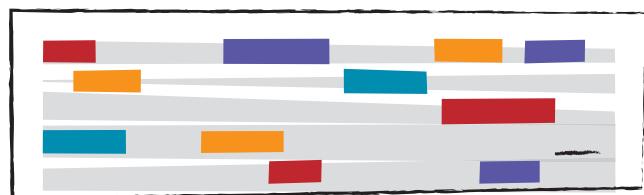
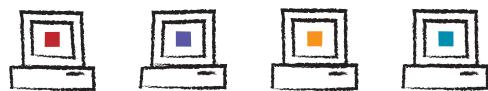


# Parallel Processing

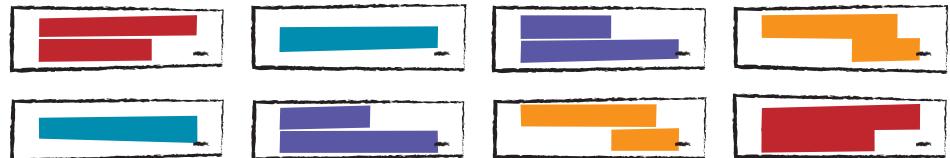
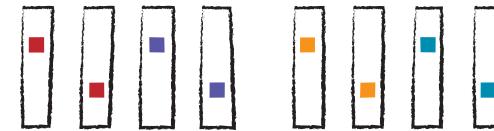
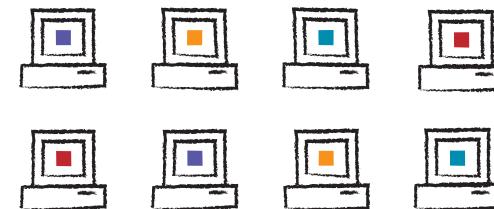


# The Idea – a sketch

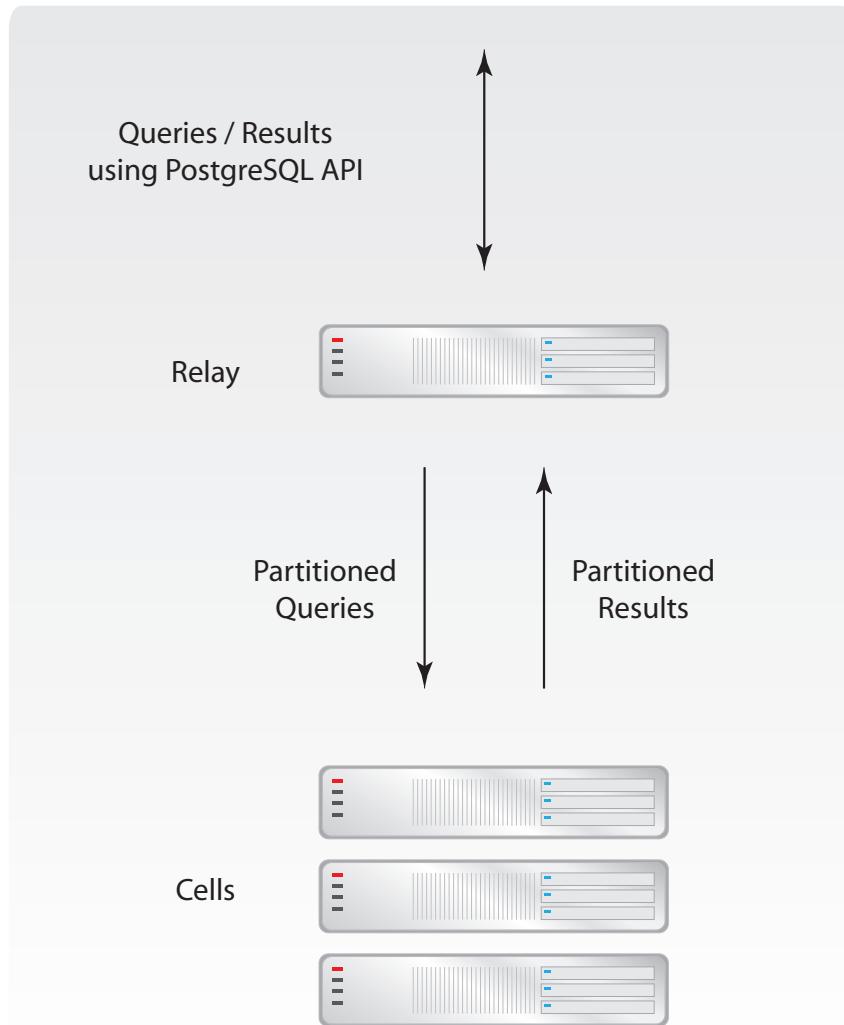
Serial Processing



Parallel Processing



# From serial queries to parallel queries



- **layout** defines distribution
  - of tables
  - on cells
  - via attributes
  - using a degree of parallelism (dop)
- **relay** grid gateway
  - provides a standard PostgreSQL interface for clients
  - plans distributed queries
  - combines grid results
- **cells** hold partitioned data
- **redundancy group**
  - one complete copy of the data



# Performance



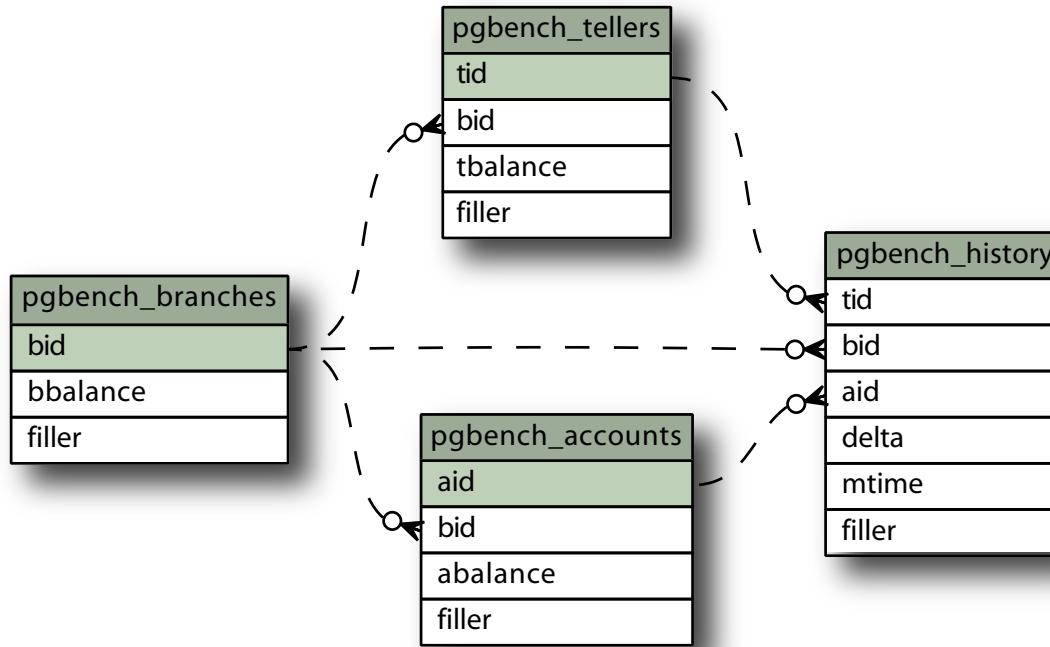
# Test platform

- Simple grid
  - one location
  - one redundancy group
  - and upto 10 hosts
- Each host is
  - AMD X3 720
  - 16GB PC6400 DDR2
  - 3x WD RE3 250GB SATA
  - XFS, barrier = off
- 1Gb network



# Test database

- Consider the pgbench ERD:



- With a layout “per\_account”
  - distribution key accounts.aid and history.aid



# Select test

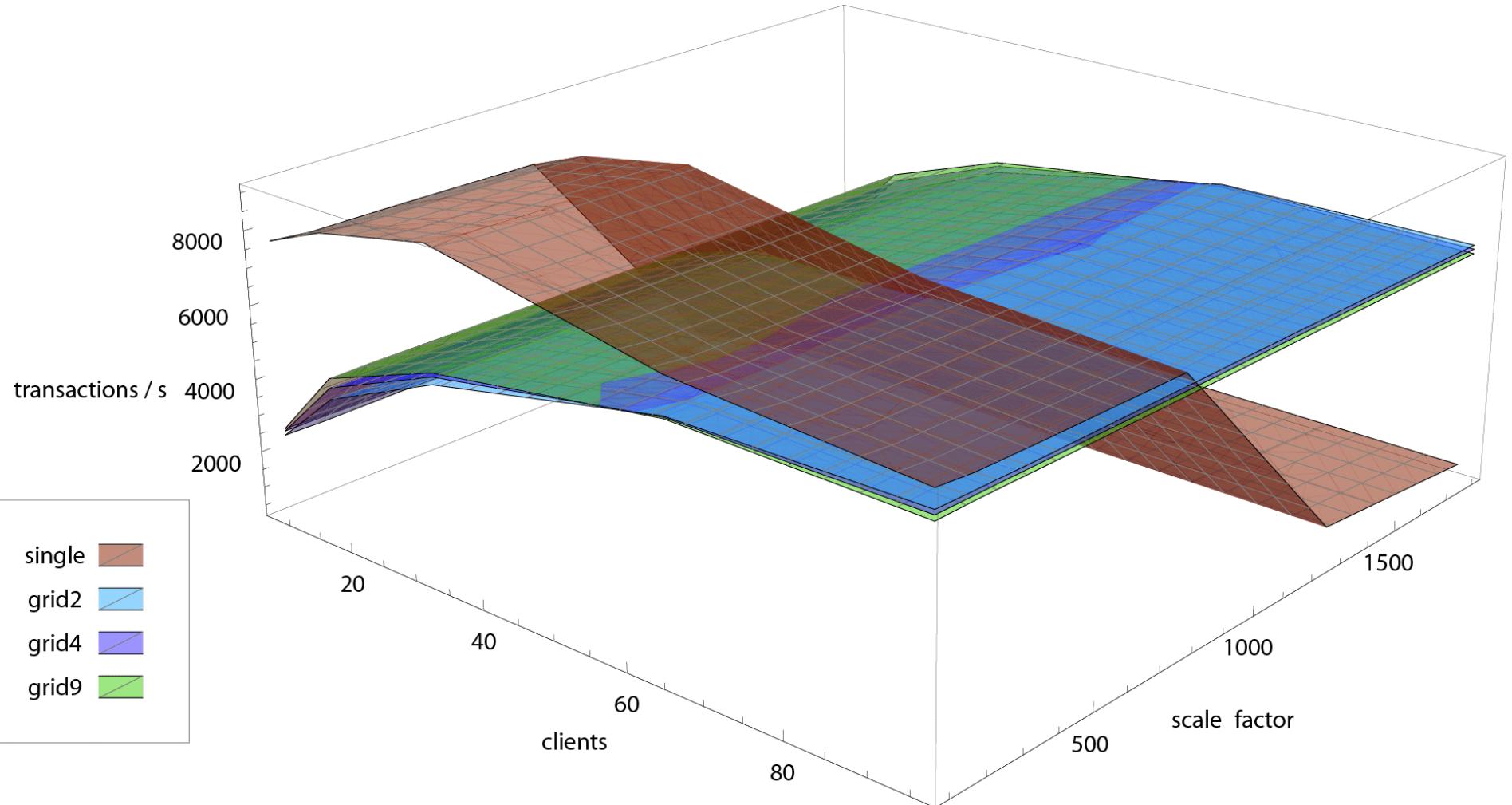
- Determine read only / select speed
- Query

```
SELECT abalance, filler FROM pgbench_accounts WHERE aid = :aid
```

- Platform configuration
  - single host or
  - layout per\_account dop  $\in [2, 4, 9]$  and #hosts = dop
- pgbench configuration:
  - #clients  $\in [8, 16, 32, 64, 96]$
  - scale\_factor  $\in [100, 200, 400, 800, 1300, 1800]$



# Select results



# TPC-B test

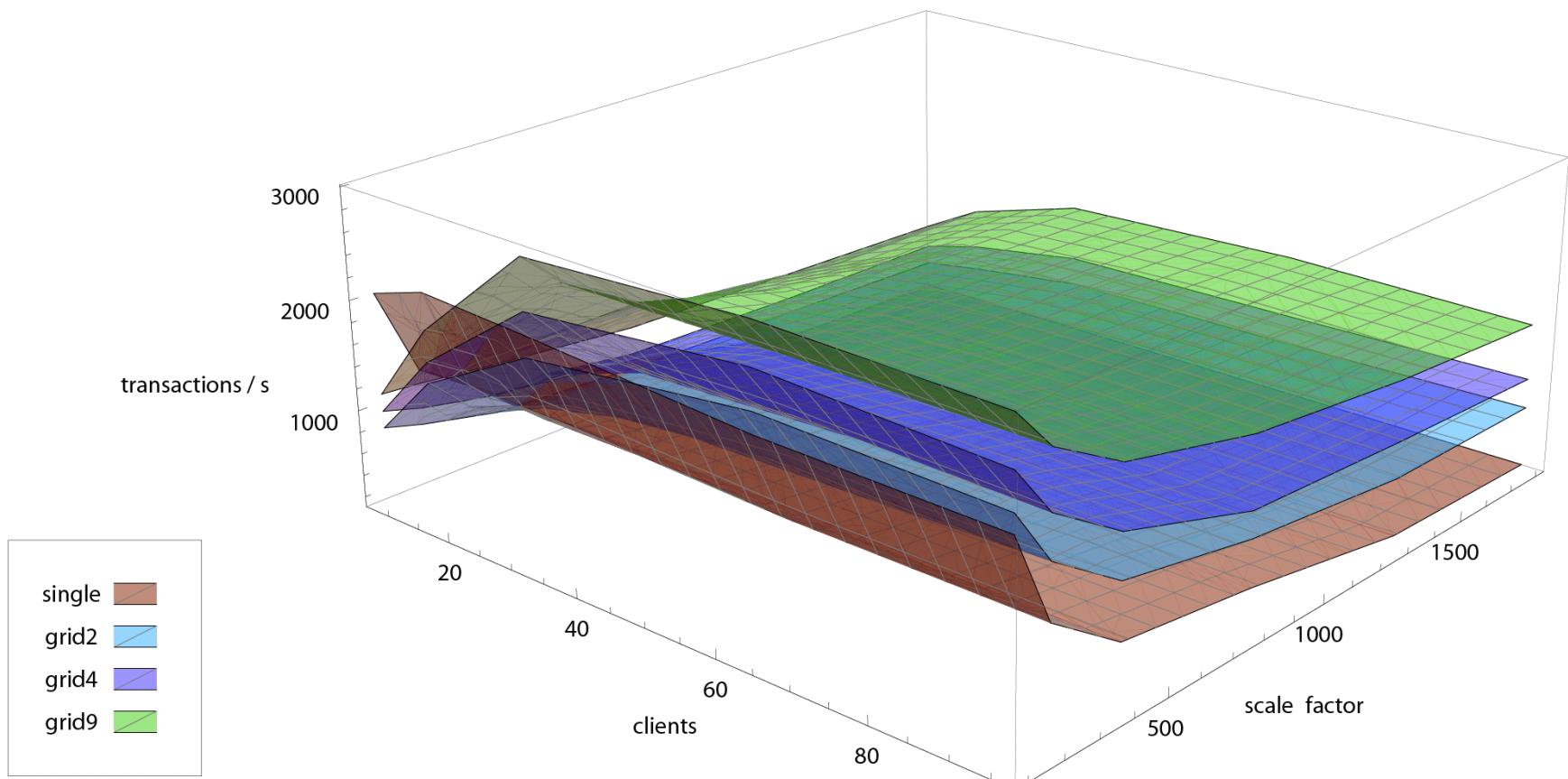
- Determine “TPC-B” transaction speed
- Query

```
BEGIN
  UPDATE pgbench_accounts SET abalance = abalance + :delta WHERE aid = :aid
  SELECT abalance FROM pgbench_accounts WHERE aid = :aid
  UPDATE pgbench_tellers SET tbalance = tbalance + :delta WHERE tid = :tid
  UPDATE pgbench_branches SET bbalance = bbalance + :delta WHERE bid = :bid
  INSERT INTO pgbench_history (tid, bid, aid, delta, mtime)
    VALUES (:tid, :bid, :aid, :delta, CURRENT_TIMESTAMP)
END
```

- Platform and test configuration as before



# TPC-B results



# Mixed load test

- Determine results for a Portavita like mixed load

$$\text{Query} = \begin{cases} \text{select} & 90\% \\ \text{tpc-b} & 9.9\% \\ \text{complex} & 0.1\% \text{ of the time} \end{cases}$$

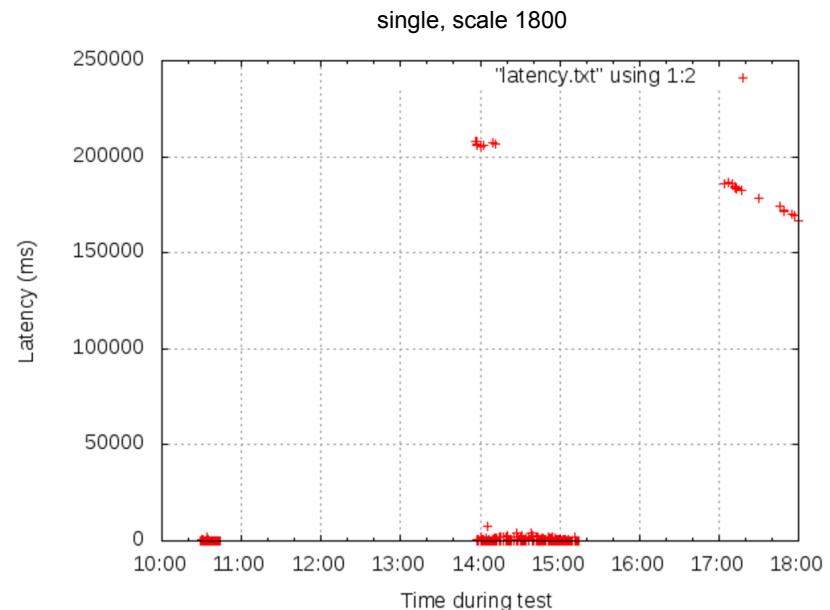
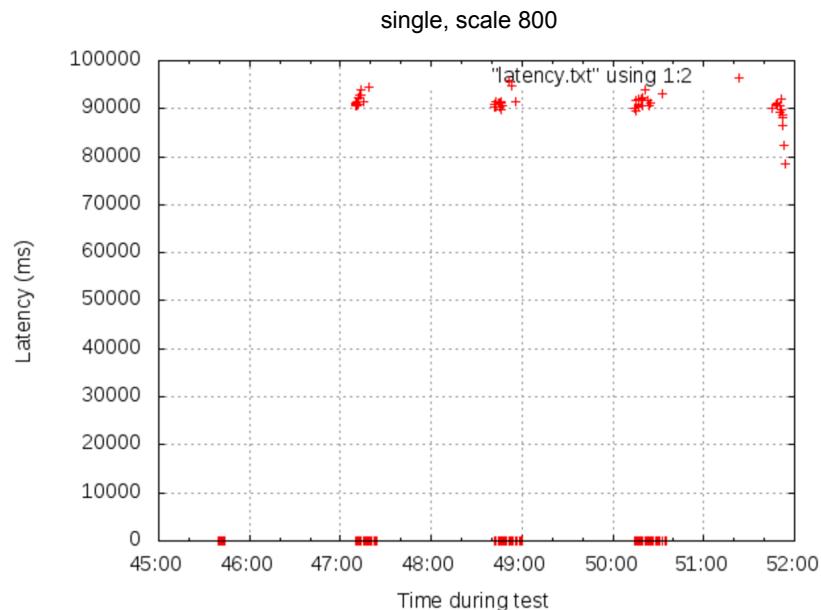
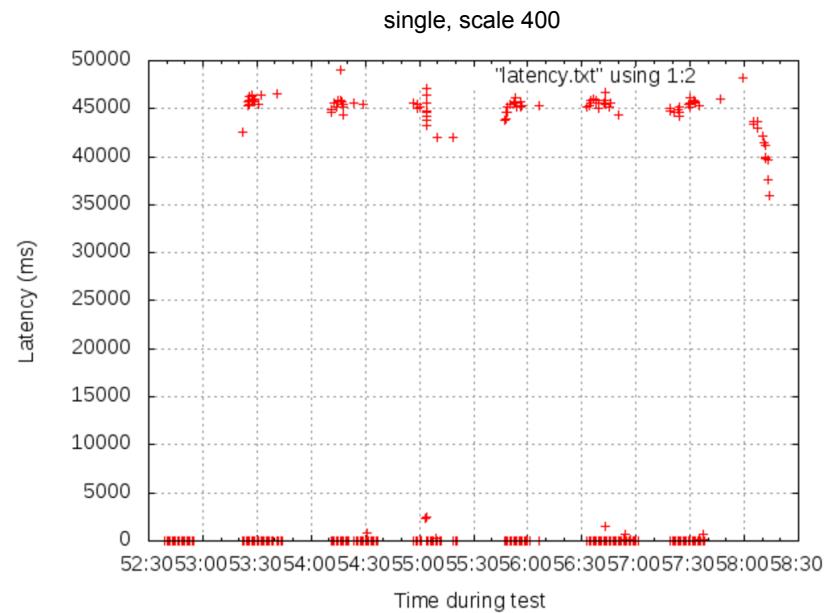
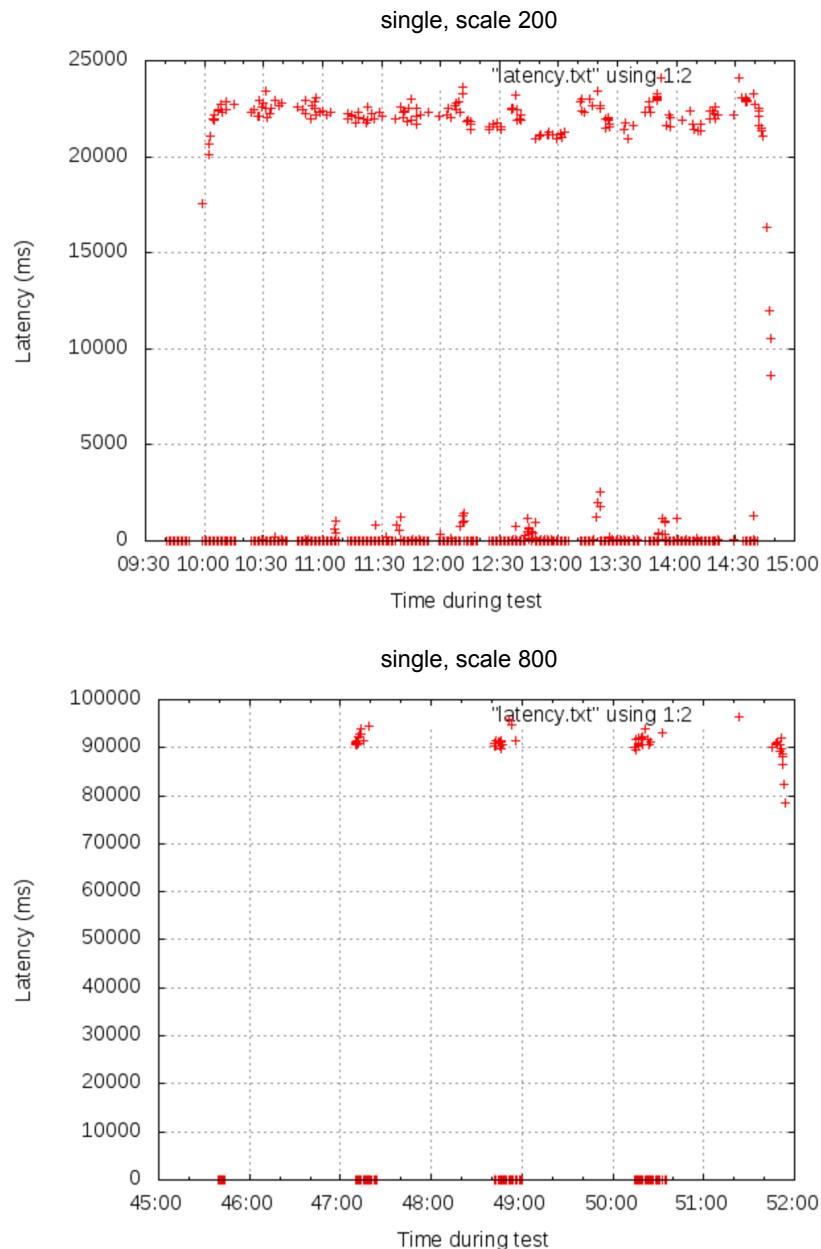
- Where complex is

```
SELECT a.bid, avg(abalance) AS b FROM pgbench_accounts a  
WHERE a.bid= :bid GROUP BY a.bid ORDER BY a.bid
```

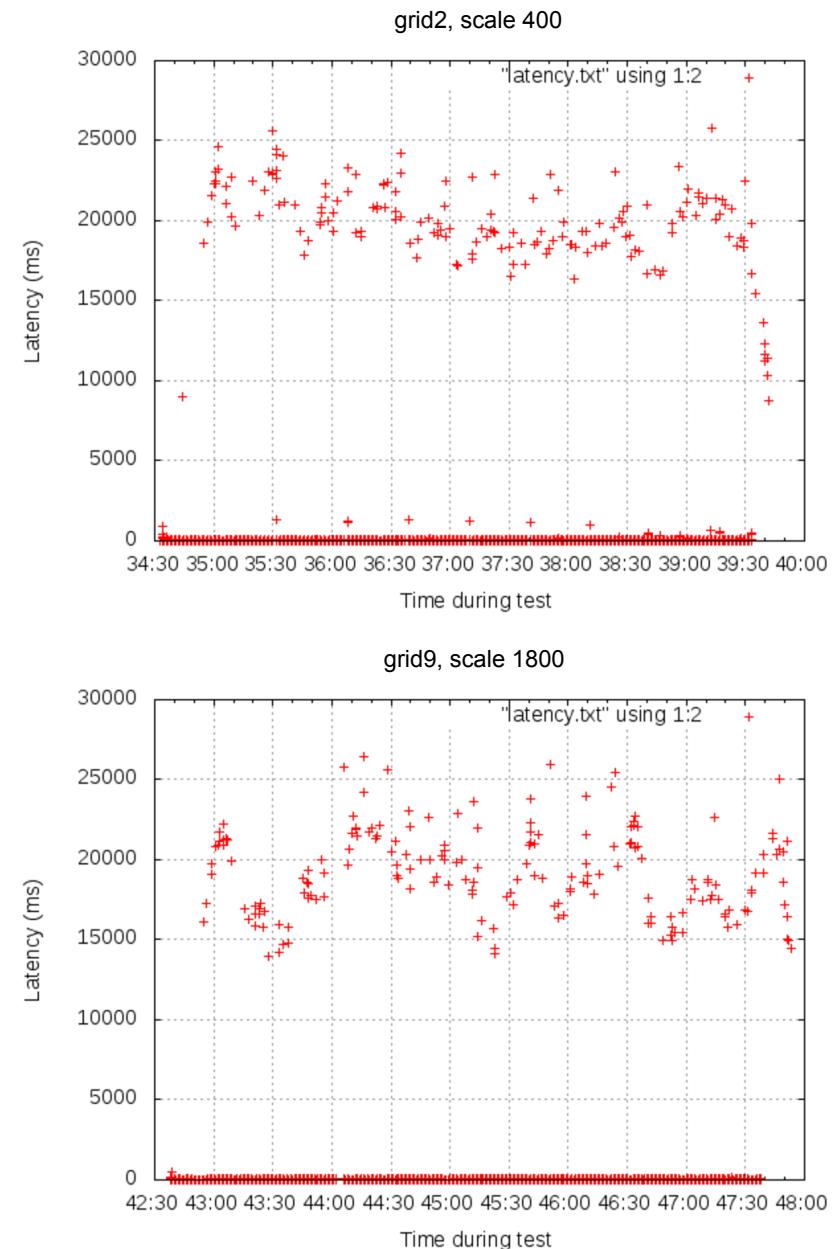
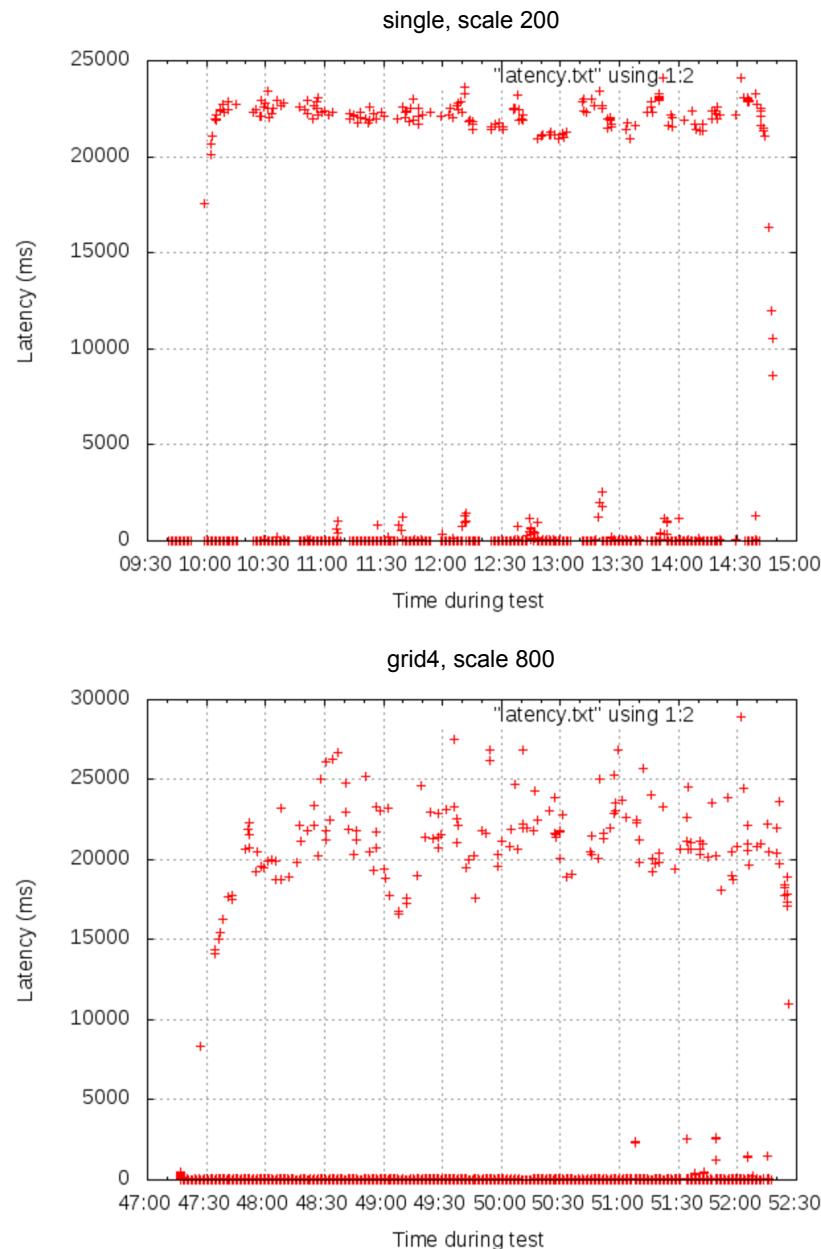
- Platform configuration as before
- pgbench configuration:
  - #clients = 16
  - scale\_factor ∈ [200, 400, 800, 1800]



# Mixed load latencies, 1 server



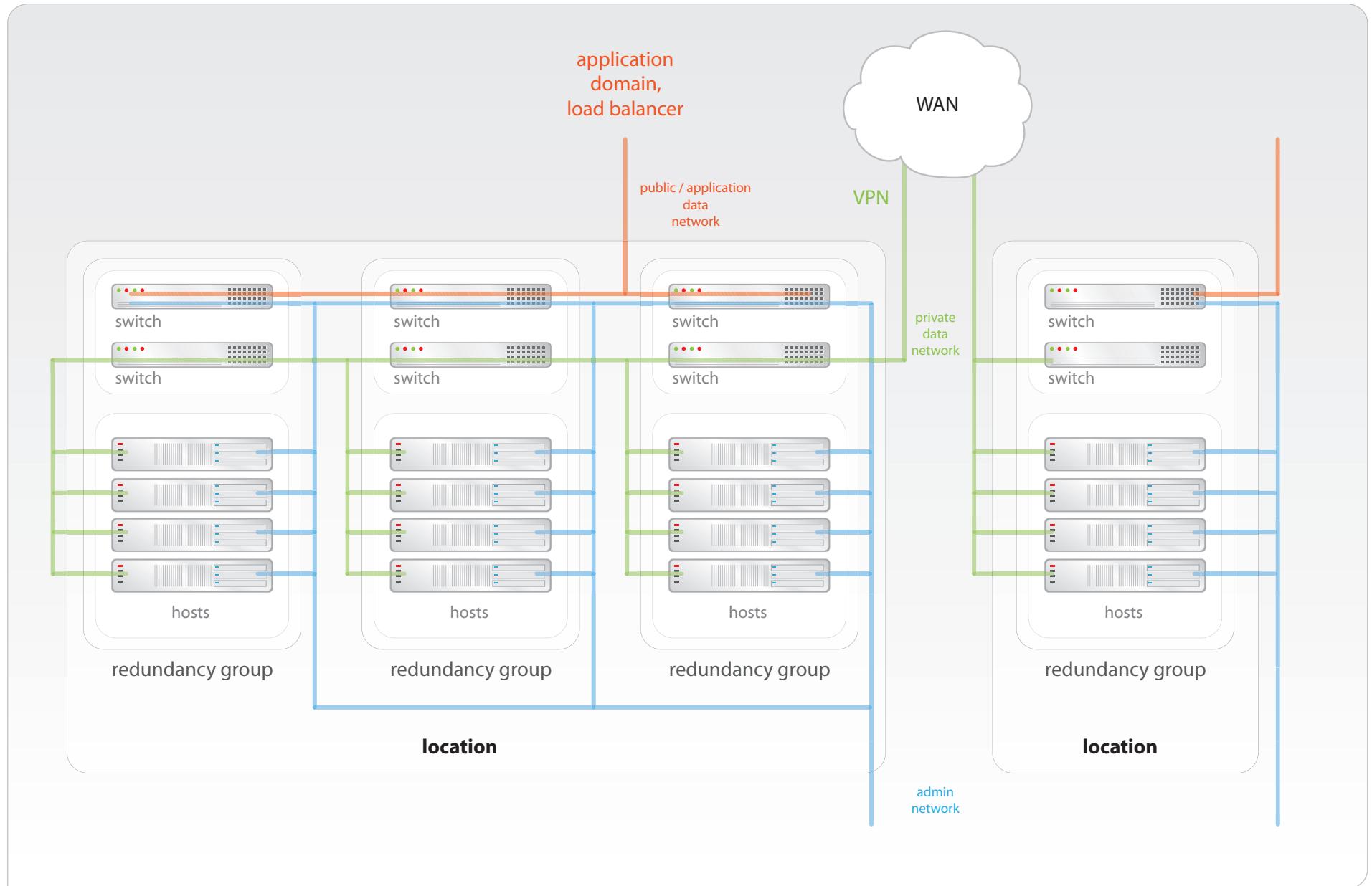
# Mixed load latencies, grid, constant shard size



# **Back to Portavita**



# Deploy with redundancy



# Conclusions

- Parallel PostgreSQL is a solution for mixed OLTP / OLAP use cases, provided your data is partitionable
- Control complex query response time with shard size
- Healthcare Datatypes as UDTs (instead of ORM) increases developer productivity



# Questions



# References

- E.F. Codd - Relational Database: A Practical Foundation for Productivity, ACM Turing Award Lecture, 1981
- Urs Hözle - The Google Linux Cluster, 2002
- M. Stonebraker, R. Cattel - 10 Rules for Scalable Performance in 'Simple Operation' Datastores, 2011
- Wikipedia - Memory Wall
- G. Smith - pgbench-tools
- J.D. McCalpin - STREAM: Sustainable Memory Bandwidth in High Performance Computers
- G. Smith - Stream scaling - Automate memory bandwidth testing with STREAM using various core counts
- Y.T. Havinga, W.P. Dijkstra and A. de Keijzer - Adding HL7 version 3 data types to PostgreSQL, 2010
- G. Schadow - The Unified Code for Units of Measure, 2009



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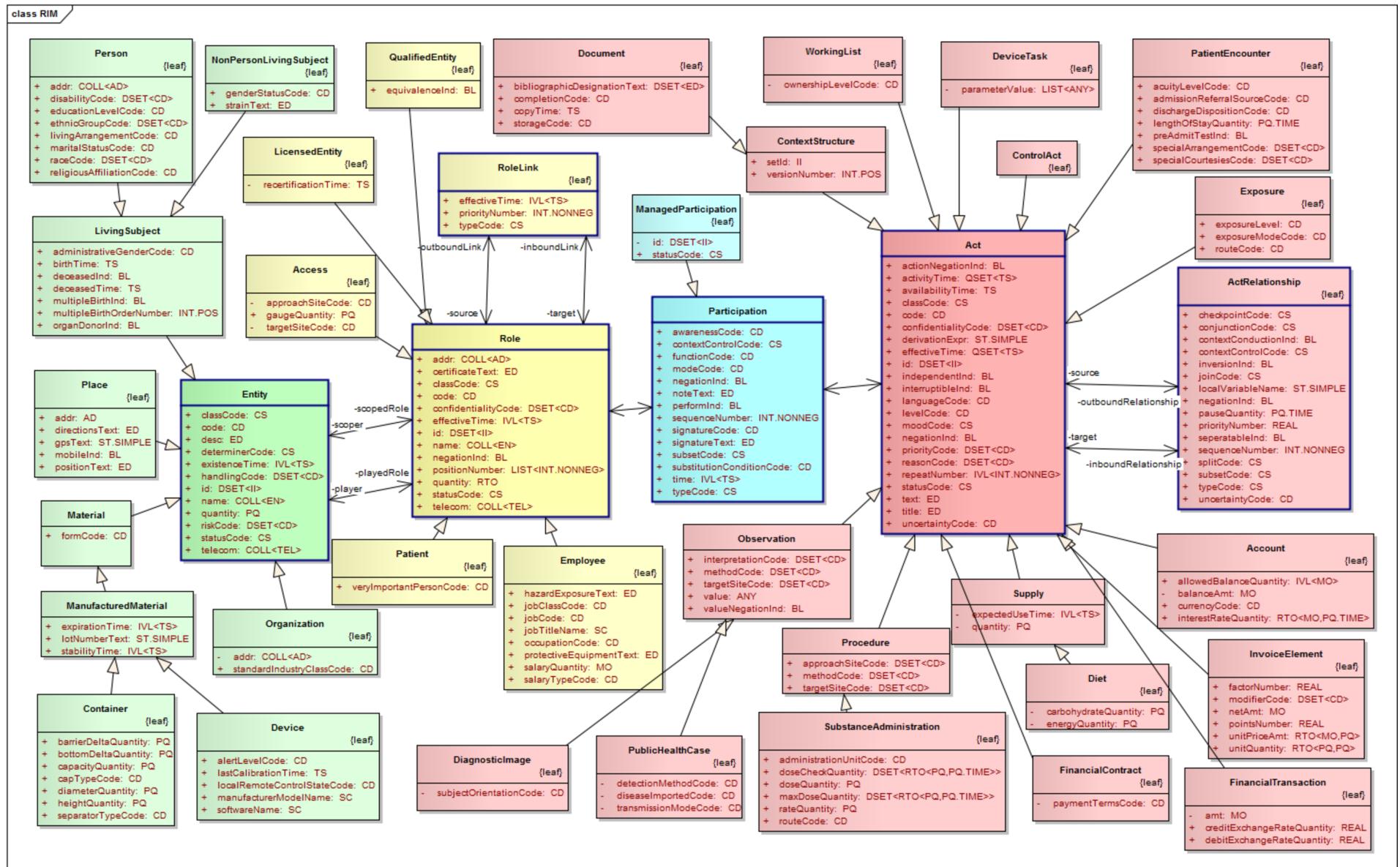
PO BOX 1287  
1000 BG Amsterdam  
The Netherlands



# Backup slides



# HL7v3 reference information model



Source: Grahame Grieve

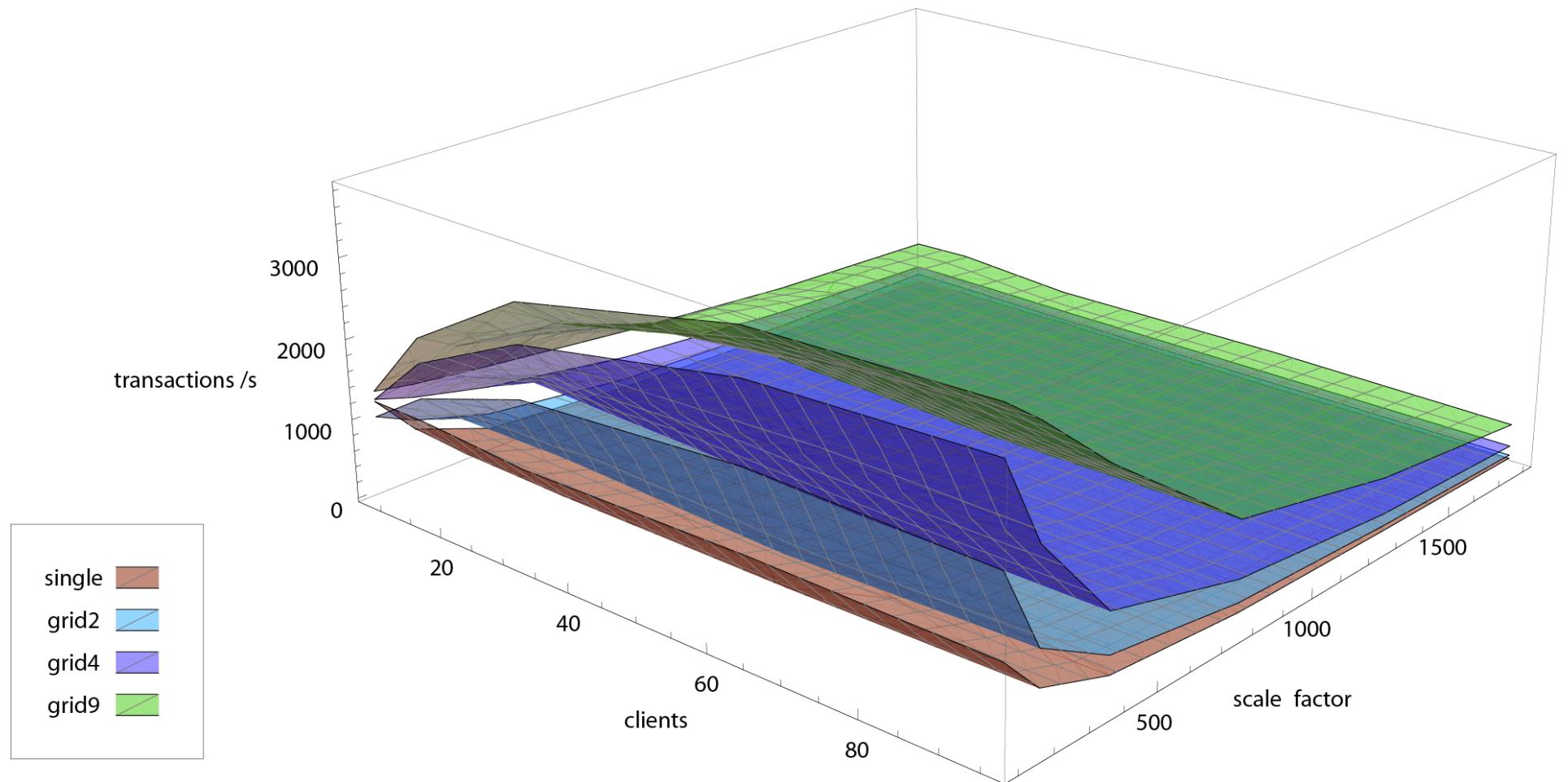


# Interval and sets of point in time

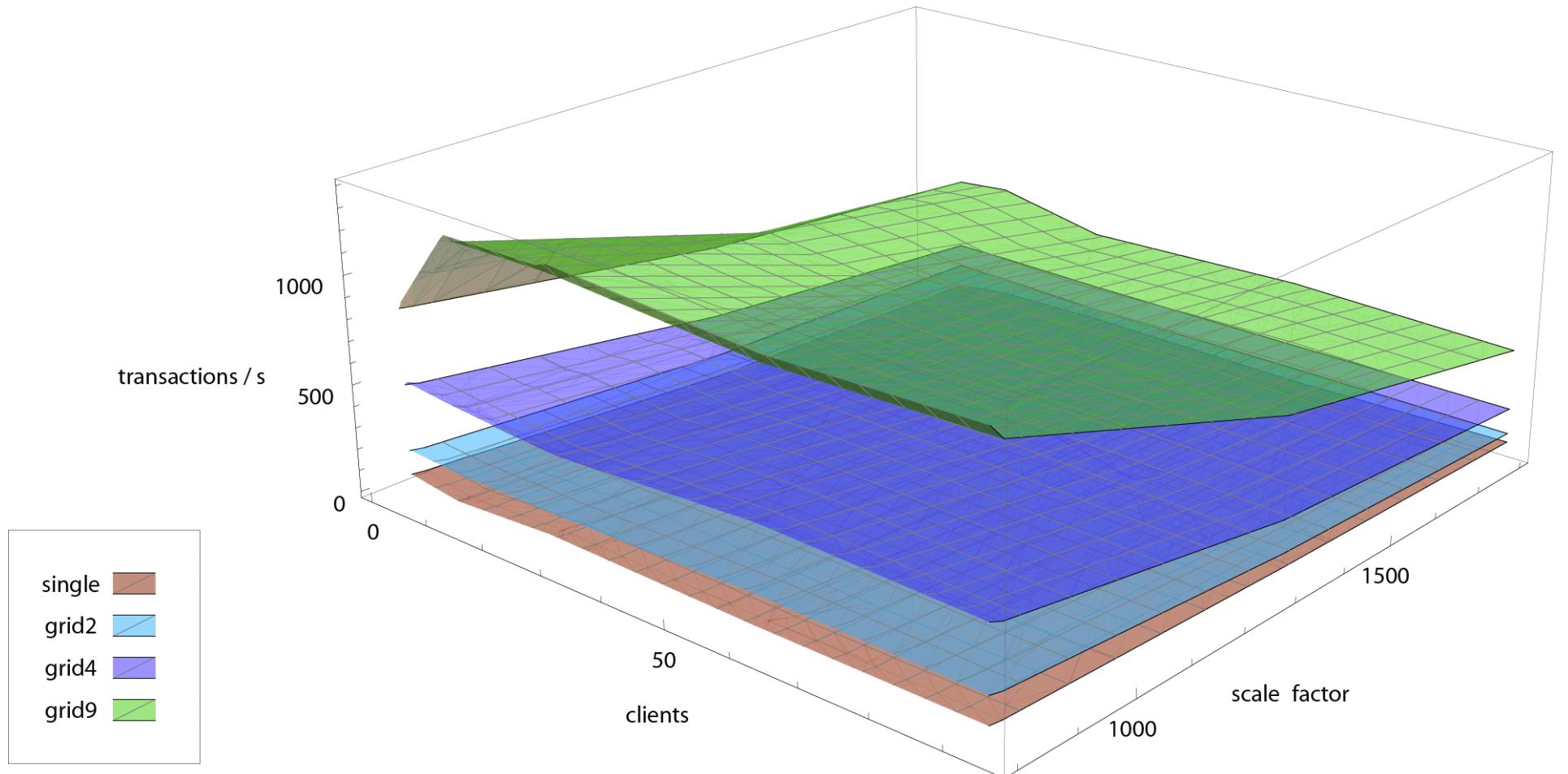
- Point in time is relevant to every query
- HL7v3 Point in Time implementation
- Operations supported:
  - Comparison: **overlaps**, **contains**
  - Arithmetic: **+**, **-**, **intersect**
  - Aggregation: **sum**
  - Construction: **intervalafter** and friends
- Indexable



# Mixed load results



# Mixed load results – zoom



# Mixed load test 2

- Determine results for a Portavita like mixed load

Query = 
$$\begin{cases} \text{select} & 90\% \\ \text{tpc-b} & 9.9\% \\ \text{complex} & 0.1\% \text{ of the time} \end{cases}$$

- Where complex is

```
SELECT h.tid as teller, SUM(delta), a.aid as account, AVG(abalance)
  FROM pgbench_history h
  JOIN pgbench_accounts a ON a.aid=h.aid
 WHERE h.bid = :bid GROUP BY h.tid, a.aid ORDER BY h.tid
```

- Platform and test configuration as before



# Mixed load results 2

