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Minimizing Testing Overheads in Database Migration Lifecycle

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Motivation: Need for DB Migration

- Functional enhancements
- Expiry of vendor support for older versions
- DB and server consolidation
  - reduce Total cost of ownership
- Mergers and acquisitions
  - reconciliation of hardware/software platforms
- Performance enhancements, workload balancing

Periodic and daunting task:
Migrate a set of production databases from one HW/SW platform to another

DB Migration Process

- Basic setup and code updates
  - Identify dependent applications
  - Code updates / conflicting SQL
  - Setup, configuration of target/test environment
- ETL
  - Schema change implementation, if any
  - Data cleansing (optional)
  - Back up the source DB
- DB configuration
  - Index generation, user roles, access rights
- Testing and Verification

Constraints on Migration Process

- Minimize business impact
  - Migrate only on non-business days
- Migration cannot happen during blackout-brownouts
- Availability
  - DBAs, Application testing team
  - Target / test hardware platforms
  - Application release schedules
- Result: Limit on size/number of databases that can be migrated during a weekend

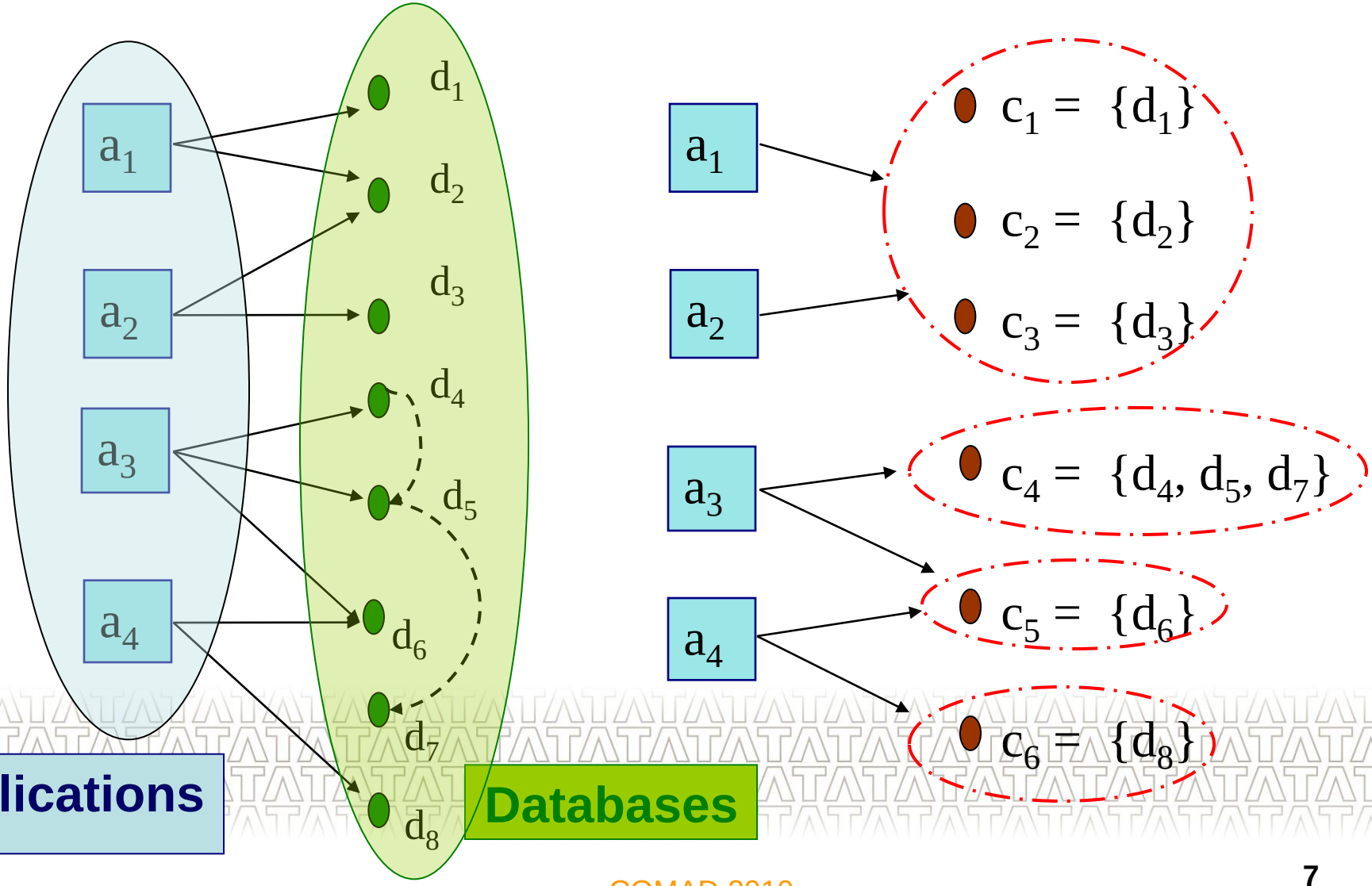
Migration Cost

- Cost components
  - C1: Basic setup and code-update
  - C2: Migration of individual DB (ETL, configuration)
  - C3: Testing all dependent applications
- C1 and C2 are more predictable / well-defined
  - Migration of individual database is well-understood
  - Automated tools exist for migration of individual database
    - QuickMig – CIKM '07, SQLways – Inspirer, SwissSQL

Testing Cost is Susceptible to Variation

- If number of DBs to be migrated is large
  - Migration over multiple weekends (migration waves)
- C3 is susceptible to large variation
  - Many-to-many App-DB dependencies
  - Complex constraints
  - Partitioning of DBs into migration waves is based on **intuition and experience** of DBAs
  - Little/no formal, quantitative analysis to support decision-making
  - C3 can increase due to re-testing of applications

A Simple Example



DBMP as an optimization problem

- **Input:** set **A** of applications which use the databases in set D and a cost function for application testing
- **Output:** Partitions of databases into a set of migration waves **W**
- **Objective:** Minimize total application testing cost

$$\text{Minimize: } f(W) = \sum_{k=1}^{|W|} \sum_{j:a_j \in A_{w_k}} t_j$$

- **Constraint:** Size of each wave should not exceed Smax

$$\sum_{i:d_i \in w_k} s_i \leq S_{max}$$

DBMP is NP-hard

- SET-PARTITION can be reduced to DBMP

$$S_{max} = \frac{1}{2} \cdot \sum_{s \in I} s$$

- Hyper-graph partitioning can be reduced to DBMP
  - Databases as nodes of hyper-graph
  - Applications as hyper-edges
  - Testing cost obtained using hyper-edge cuts

Proposed Solutions

- ILP based optimal solution for small problem instances
- Hyper-graph partitioning using hMETIS [U-MN]
  - May violate the wave size Smax constraint
- WAVE-FIT
  - Cost as good as hMETIS
  - Also honors the wave size constraint

Int. Linear Programming solution

- Objective

$$\text{Minimize: } \sum_{k=1}^{|W|} \sum_{j=1}^{|A|} a_{jk} t_j. \quad (1)$$

- Constraints

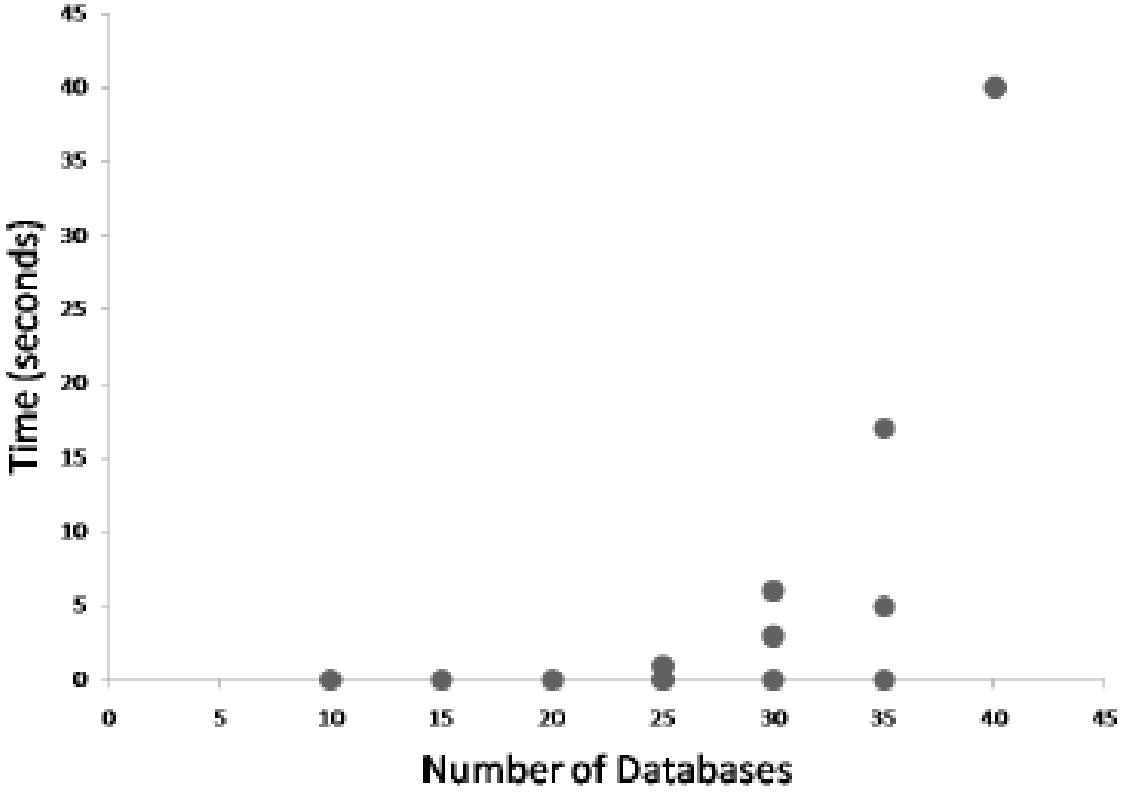
$$\forall k, \sum_{i=1}^{|D|} s_i d_{ik} \leq S_{max}, \quad (2)$$

$$\forall i, \sum_{k=1}^{|W|} d_{ik} \geq 1. \quad (3)$$

$$\forall j, k, \sum_{i:d_i \in D_j} d_{ik} \leq |D_j| \cdot a_{jk}. \quad (4)$$

ILP applicability limited

- Though optimal, useful for small problem instances only



hMETIS: hyper-graph partitioning tool

- Construction of a hyper-graph H for a given DBMP
  - Databases as nodes of hyper-graph
  - Applications as hyper-edges
- Solving DBMP for |W| migration waves is same as |W|-way partition of hyper-graph H
  - Weights of hyper-edge = particular application testing cost
  - Total cost = hyper-edge cuts + number of Apps

hMETIS…

- hMETIS provides good solutions
  - For many problems, cost is close to lower bound
  - But it may violate the wave-size constraint Smax
    - no strict upper-bound on partition size
  - Violation can in significant number of waves (upto 40%)

WAVE-FIT algorithm

- Sort (ascending order) applications based on number of databases used
- For each app a_j:
  - g = set of DBs used by a_j
  - If sizeof(g) < S_{max}:
    - Repeat
      - Find an app a_p such that D_p has maximum overlap with **g**
      - If the combined size of **g** and D_p < S_{max} :
        - » merge **g** and D_p to form the new **g**
    - Until **sizeof(g)** < S_{max}
  - Else:
    - Partition g to satisfy the S_{max} constraint

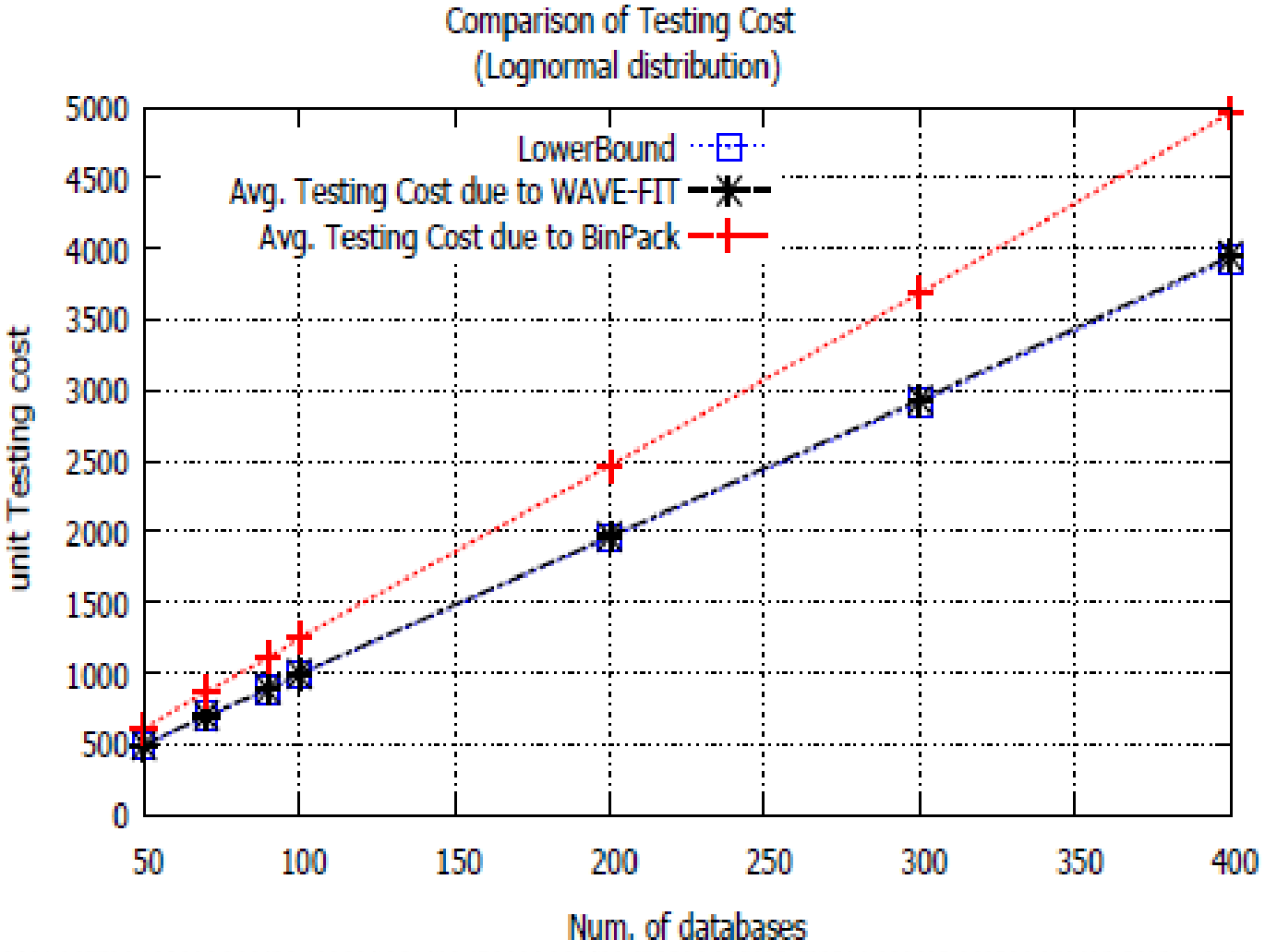
Evaluation

- Real-life problem
  - 191 apps, 116 DBs, 204 dependency edges
  - Both hMETIS and WAVE-FIT give optimal cost solution
- Experimental evaluation
  - Generated synthetic datasets based on real-life datasets
  - DB sizes
    - Lognormal (6.18, 2.79)
    - Uniform (10, 500000)

Table 1: Experimentation Scenarios

	$\|A\|/\|D\|$	$\|B\|/\|D\|$
Experiment 1	1.1	1.25
Experiment 2	1.5	1.75
Experiment 3	1.75	2.0
Experiment 4	2.0	2.25
Experiment 5	2.5	2.8
Experiment 6	3.0	3.3

Comparison with naïve (bin-pack) approach



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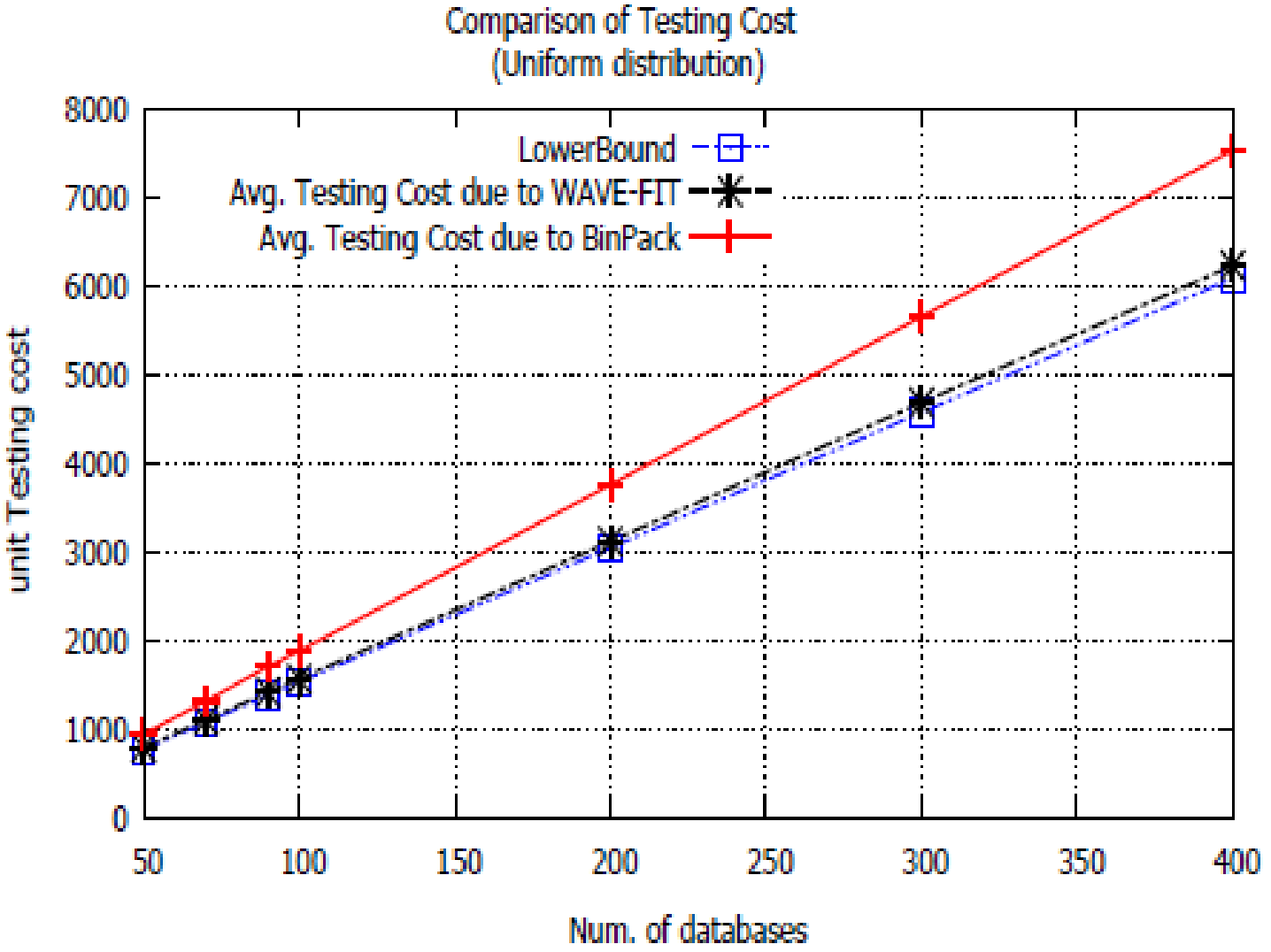


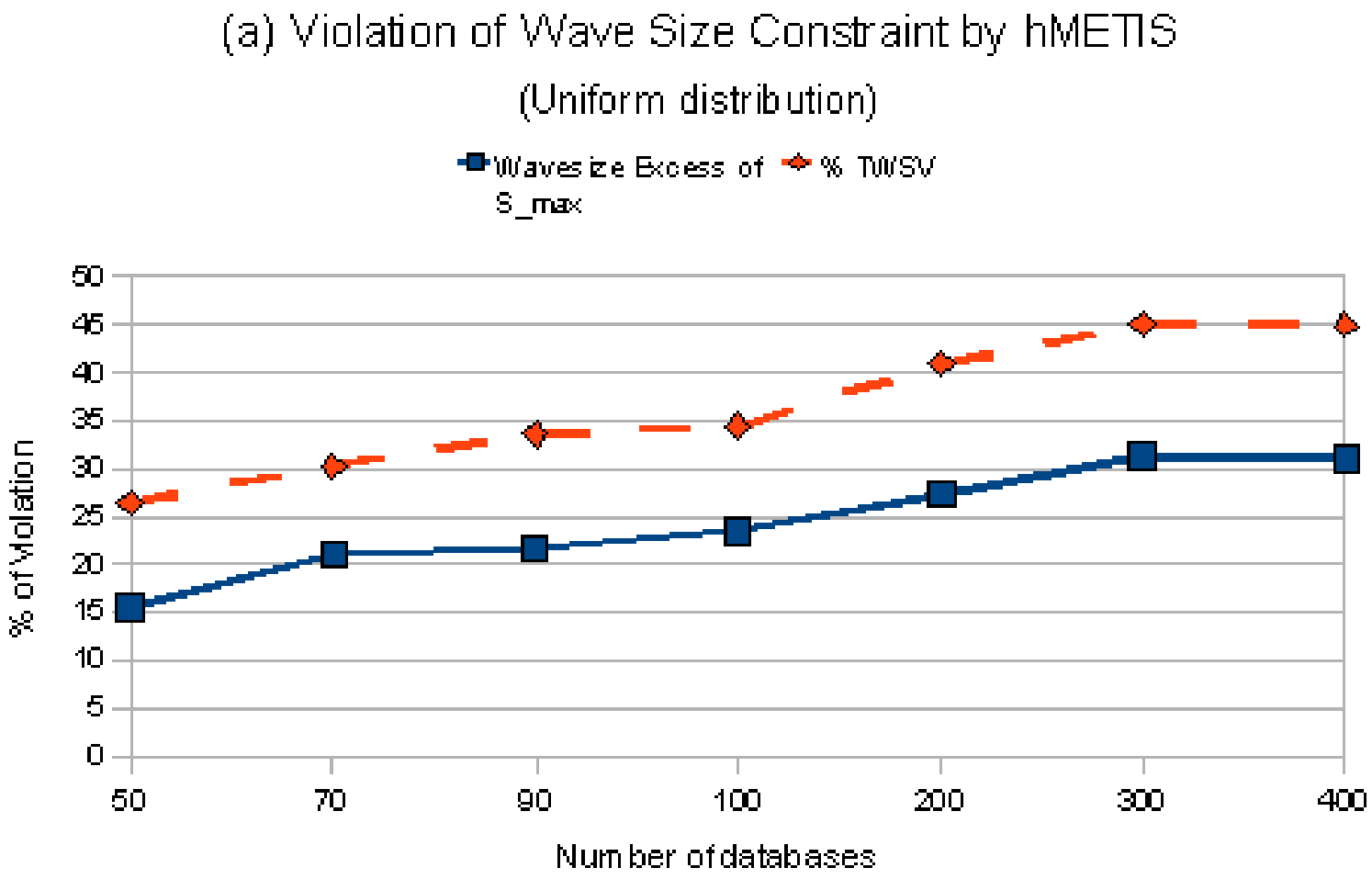
Testing cost using hMETIS and WAVE-FIT

U_h = testing cost due to hMETIS (Uniform case)
U_w = testing cost due to WAVE-FIT (Uniform case)
L_h = testing cost due to hMETIS (Lognormal case)
L_w = testing cost due to WAVE-FIT (Lognormal case)

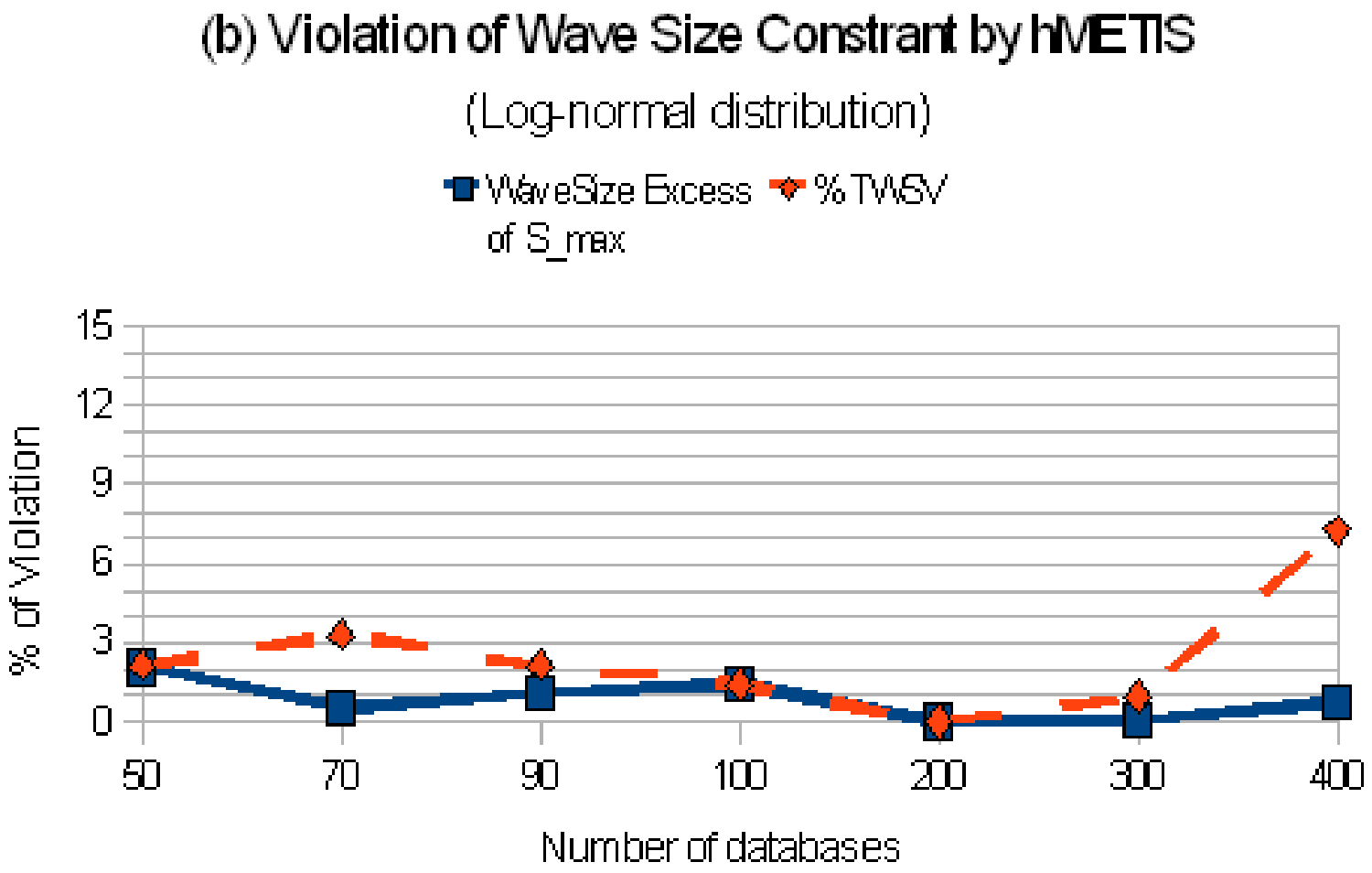
Table 2: Ratio of Testing Costs by hMETIS and WAVE-FIT

	U_h/U_w	L_h/L_w
Experiment 1	1.00	1.00
Experiment 2	1.00	0.99
Experiment 3	1.00	1.00
Experiment 4	1.00	1.00
Experiment 5	1.01	1.00
Experiment 6	1.01	1.00

Violation of wave size constraint by hMETIS



Violation of wave size constraint by hMETIS



Summary

- Identification/Formalization of DBMP
  - a recurrent, important problem in the industry
- DBMP is NP-hard
- Three solutions
  - ILP based
  - Hyper-graph based
  - WAVE-FIT
- Characterization of realms where each of these solutions can be appropriate

Thanks !

Questions ?