Decentralized Orchestration of Data-centric Workflows Using the Object Modeling System

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Agenda

- Introduction
- Object Modeling System (OMS)
- AURIN Project
- OMS-based Workflows
- OMS Service Orchestrations
- Experimental Results
- Conclusions

INTRODUCTION

- Service-oriented Architecture
  - Web services
- Workflow Technologies
  - Coordinate a collection of services
- Workflow implementation approaches
  - Service Orchestration
    - Centralized engine → bottleneck for **data-centric** workflows
  - Service Choreography
    - Distributed control
- Goal: a new framework to implement data-centric workflows based on Object Modeling System (OMS)

Object Modeling System (OMS)

- A framework to implement science model
  - Object oriented (component-based)
  - Pure Java
  - Last version: OMS 3.0
- Main features
  - Non-invasive
    - Annotation of existing languages
  - Multi-threading
    - Able to be deployed on multi-core Cluster/Cloud
  - Domain Specific Language (DSL)
    - Groovy language

COMPONENTS IN OMS

- Components
  - PJO + annotation
- Annotations
  - @In
  - @Out
  - @Execute
  - ....
- Multi-purpose components
- Automatic manual generation

Listing 1: A sample OMS3 component

```
package oms.components;
import oms3.annotations.*;

@Description("Average of a given vector.")
@Author(name = "Bahman Javadi")
@Keywords("Statictic , Average")
@Status(Status.CERTIFIED)
@Name("average")
@License("General Public License Version 3 (GPLv3)")

public class AverageVector {
    @Description("The input vector.")
    @In
    public List<Double> inVec = null;

    @Description("The average of the given vector.")
    @Out
    public Double outAvg = null;

    @Execute
    public void process() {
        Double sum;
        int c;
        sum = 0.0;
        for (c = 0; c < inVec.size(); c++)
                sum = sum + inVec.get(c);
        outAvg = sum /inVec.size();
    }
```

WORKFLOW/MODEL TEMPLATE IN OMS

- *Components* : declaration of all components
- *Parameters*: input parameters
- *Connect*: connection of components

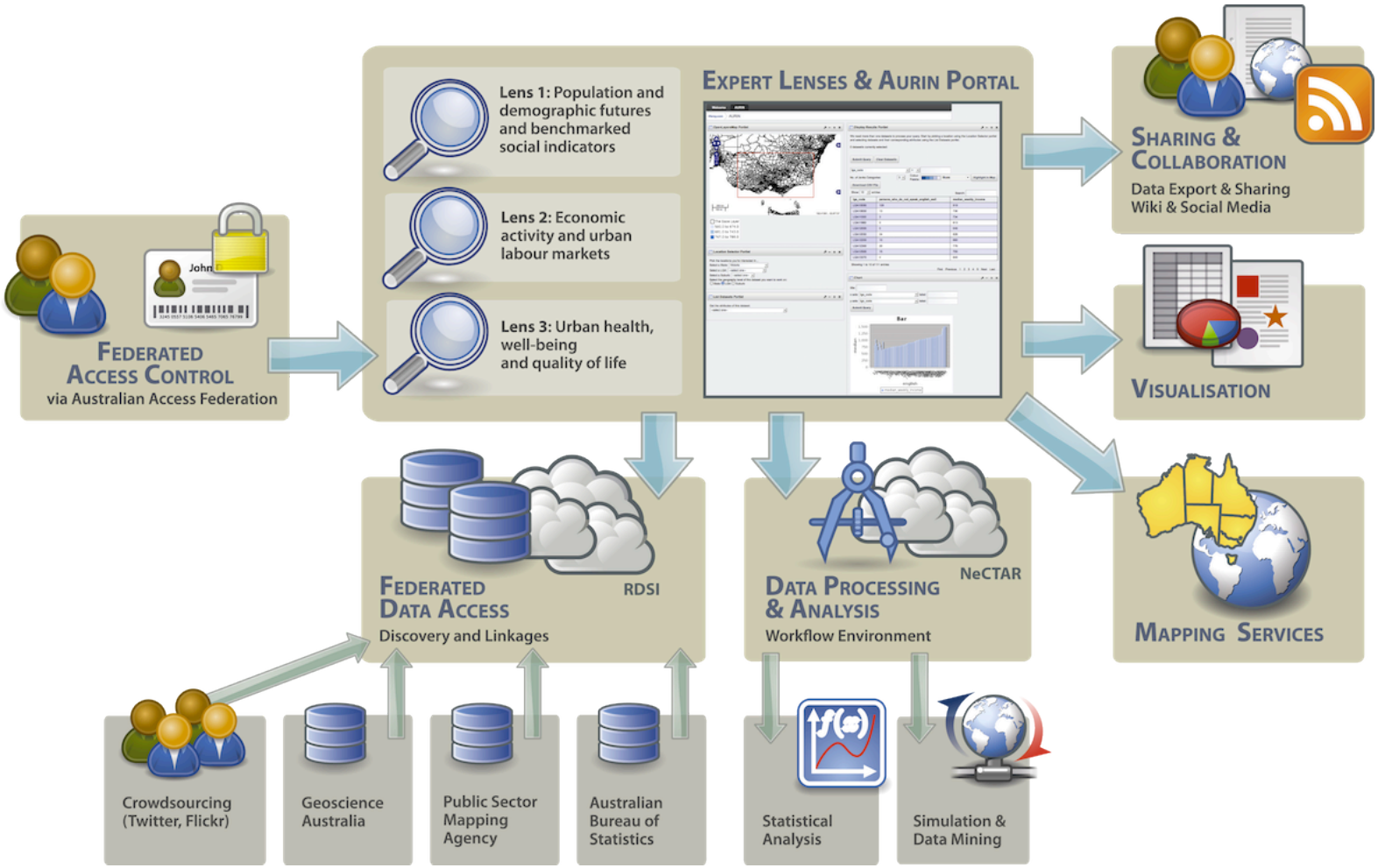
Listing 2: Model/Workflow template in OMS3

```
// creation of the simulation object
sim = new oms3.SimBuilder(logging:'OFF').sim(name:'test') {
    // the model space
    model {
        // space for the definition of the required components
        components  {
        }

        // initialization of the parameters
        parameter  {
        }

        // connection of the different components
        connect  {
        }
    }
}
// start of the simulation to obtain the results
results = sim.run();
```

AURIN Project

- Australian Urban Research Infrastructure Network (AURIN)
  - National e-Research Project (2010-2014)
  - An e-Infrastructure supporting research in urban and built environment research disciplines
  - Web Portal Application (portlet-based)
    - A lab in a browser
    - AAF Access: http://portal.aurin.org.au
    - Data discovery
    - Data visualization (Mapping service)
    - Access to the federated data source
      - Web Feature Service (WFS)
    - NeCTAR NSP and Research Cloud
    - RDSI Storage

THE AURIN ARCHITECTURE

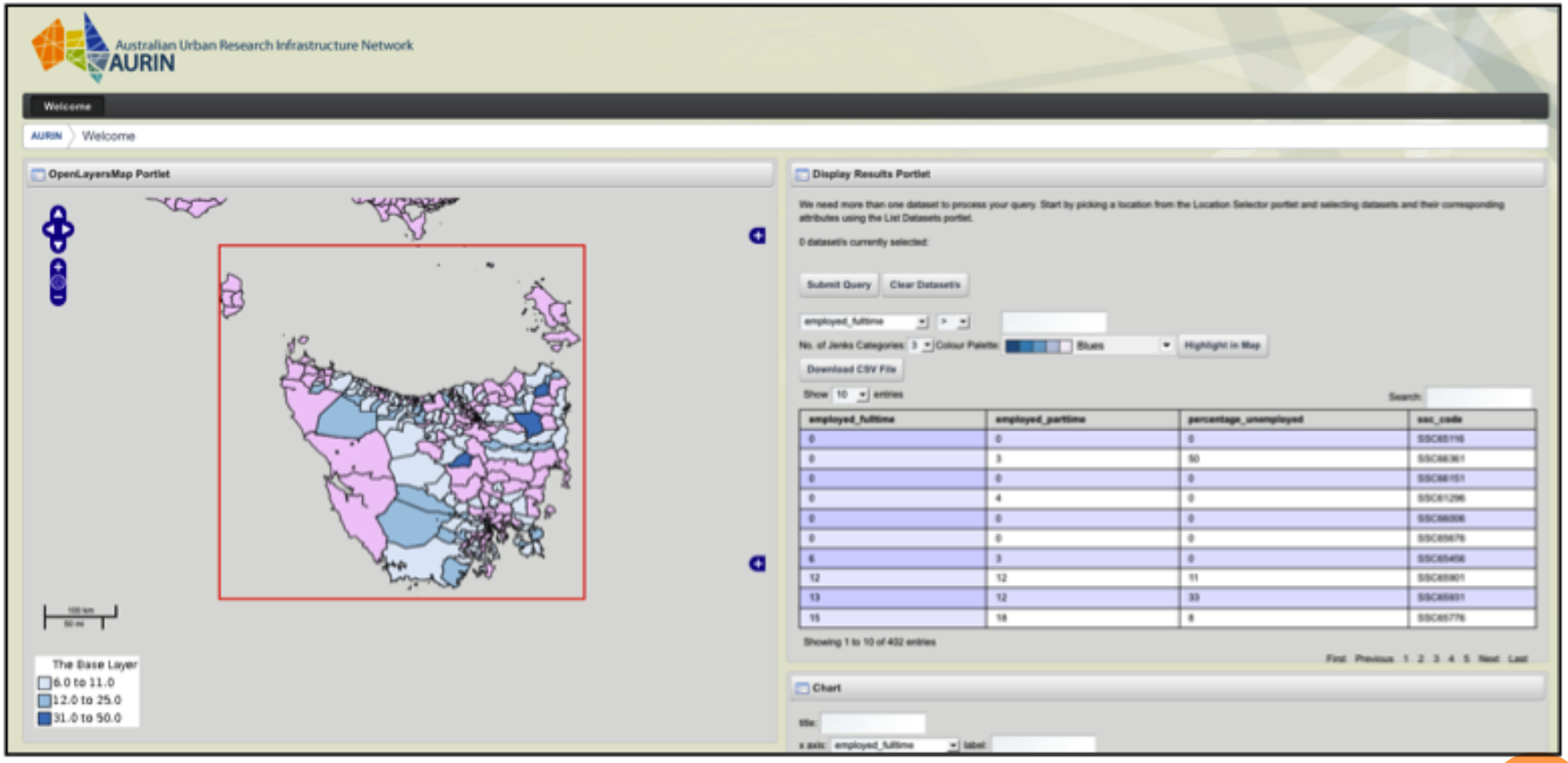


OMS-BASED WORKFLOWS

- Annotation of existing code
  - Embedded metadata using annotations
  - Attached metadata using annotations (e.g., XML file)
- Basic Components
  - Web Feature Service (WFS) Client
  - Statistical Data and Metadata eXchange (SDMX) Client
  - Basic statistical functions
- Workflow Composition
  - A standalone portlet
  - Save a workflow through web portal
    - Save as an OMS script

OMS-BASED WORKFLOWS

- Workflow in the AURIN portal



OMS WORKFLOW WITH ONE WFS CLIENT

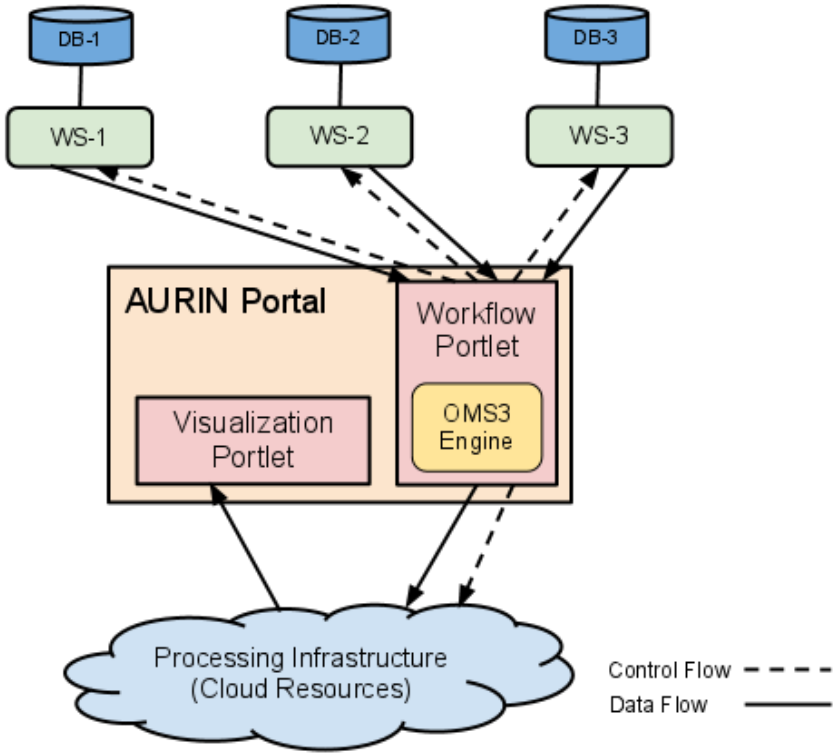
- WFS client example
  - Dataset: Landgate WA
  - Bounding box (bbox): geographical area
- DSL makes the workflow very descriptive

Listing 2: An OMS workflow with one WFS client

```
// this is an example for a wfs query
def simulation = new oms3.SimBuilder(logging:'ALL').sim(name:'wfs_test') {

model {

components {
        'wfsclient0'            'wfsclient'
}
parameter {
        'wfsclient0.datasetName'                        'ABS-078'
        'wfsclient0.wfsPrefix'                          'slip'
        'wfsclient0.datasetReference'                   'Landgate ABS'
        'wfsclient0.datasetKeyName'                     'ssc_code'
        'wfsclient0.datasetSelectedAttributes'          'ssc_code,employed_fulltime,employed_parttime'
        'wfsclient0.bbox'                               '129.001336896,-38.0626029895,141.002955616,-25.996146487500003'
}
connect {
}}
}
result = simulation.run();
```

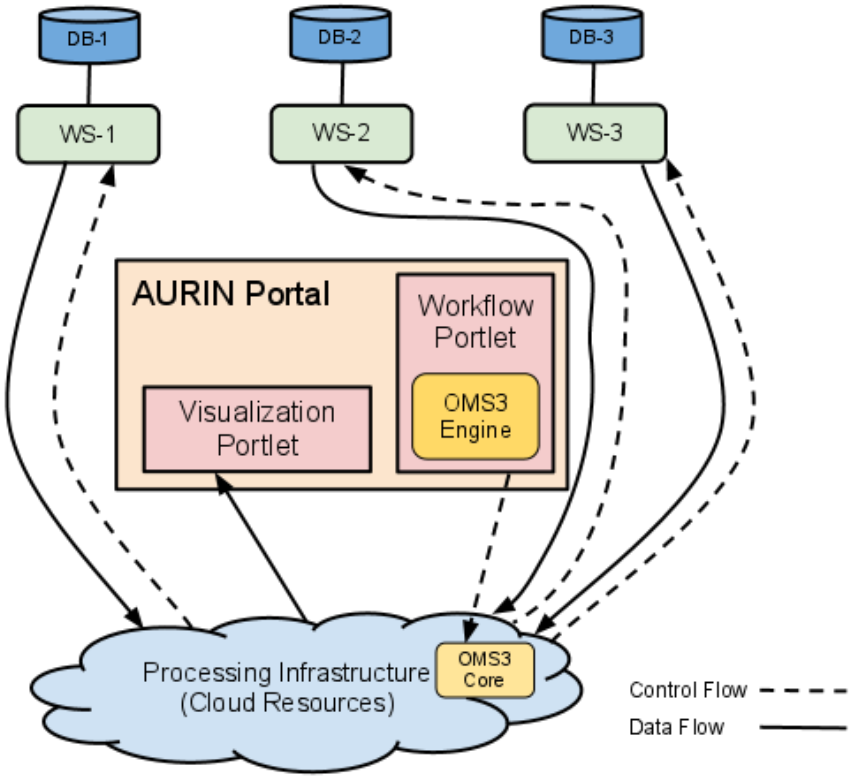
OMS Service Orchestration

- Workflow Enactment
  - Running OMS scripts by the OMS3 engine
  - Centralized service orchestration



OMS Service Orchestration

- Take advantage of the OMS3 architecture
  - Flexible and lightweight (CLI for the OM3 core)
  - Decentralized service orchestration



Cloud-based Execution

- OMS3 Features
  - Supports component-level parallelism
  - Terracotta for distributed shared memory systems
  - Run on any Cluster and IaaS Cloud
- Developed Interfaces
  - NeCTAR Research Cloud
    - Small Instance: 1-core, 4GB RAM
    - Medium Instance: 2-core, 8GB RAM
    - Extra-Large Instance: 8-core, 32GB RAM
  - Amazon's EC2

Experimental Setup

- AURIN Portal is deployed in NeCTAR NSP (4 VMs)
- Real workflow for typical urban analysis
  - Create topological spatial relationship
  - Relation: *touch*
  - Output: a topology graph shows the adjacencies of suburbs/LGA
- Input datasets

State	No. of Geometries	
	Suburbs	LGA
Western Australia (WA)	952	142
South Australia (SA)	946	136
Tasmania (TAS)	402	28
Queensland (QLD)	2112	160
Victoria (VIC)	1833	111
New South Wales (NSW)	3146	178

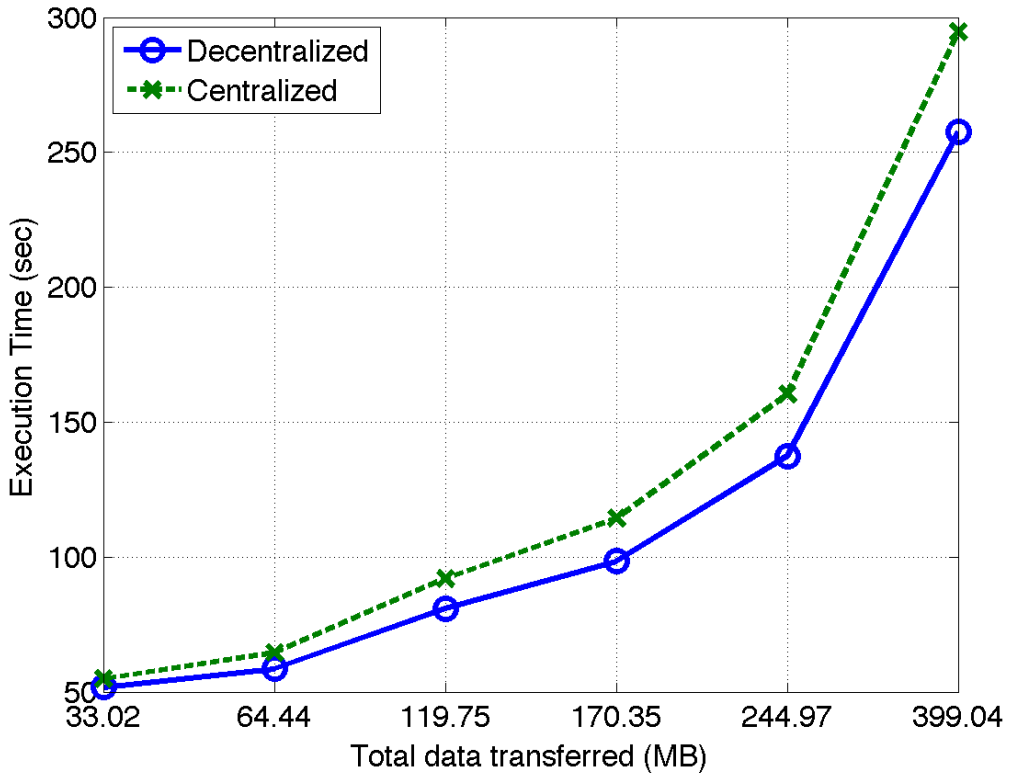
Experimental Setup

- Data-size for workflows
  - Data-centric Workflows

Workflow	**Data size (MB)**	
	Geometries	Graph
WA	33.02	2.97
WA, SA	66.44	5.90
WA, SA, TAS	119.75	6.30
WA, SA, TAS, QLD	170.35	21.53
WA, SA, TAS, QLD, VIC	244.97	33.90
WA, SA, TAS, QLD, VIC, NSW	399.04	69.43

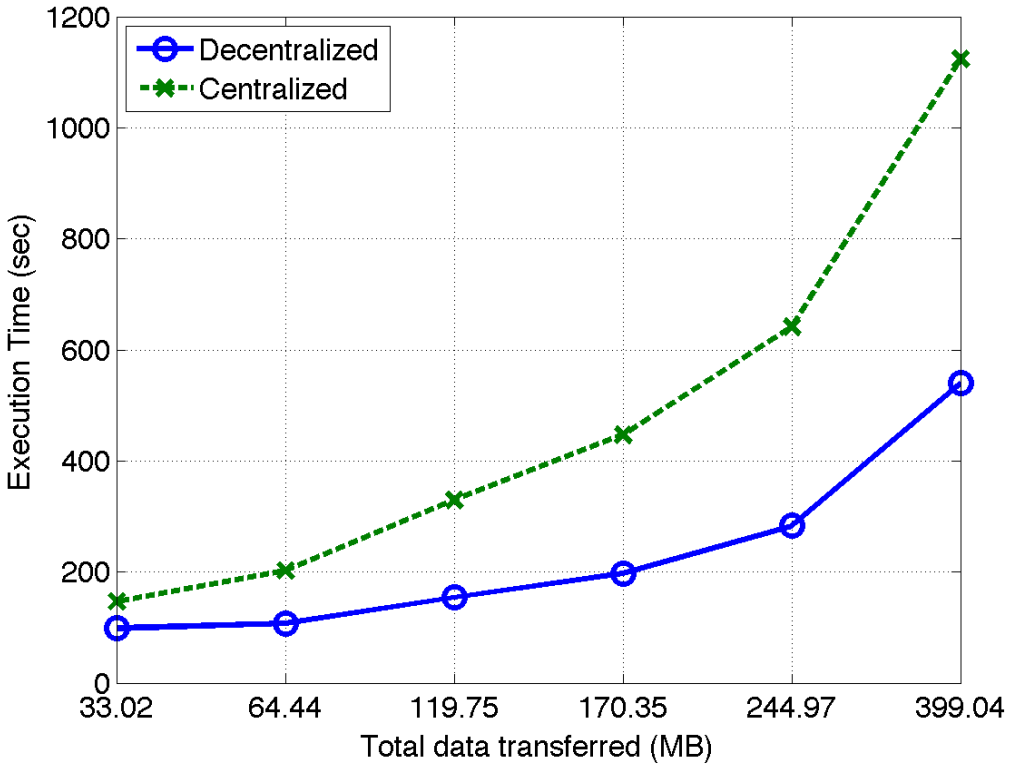
Results

- Execution time of Workflows on NeCTAR Cloud
  - Extra-Large Instance 8-core, 32GB RAM



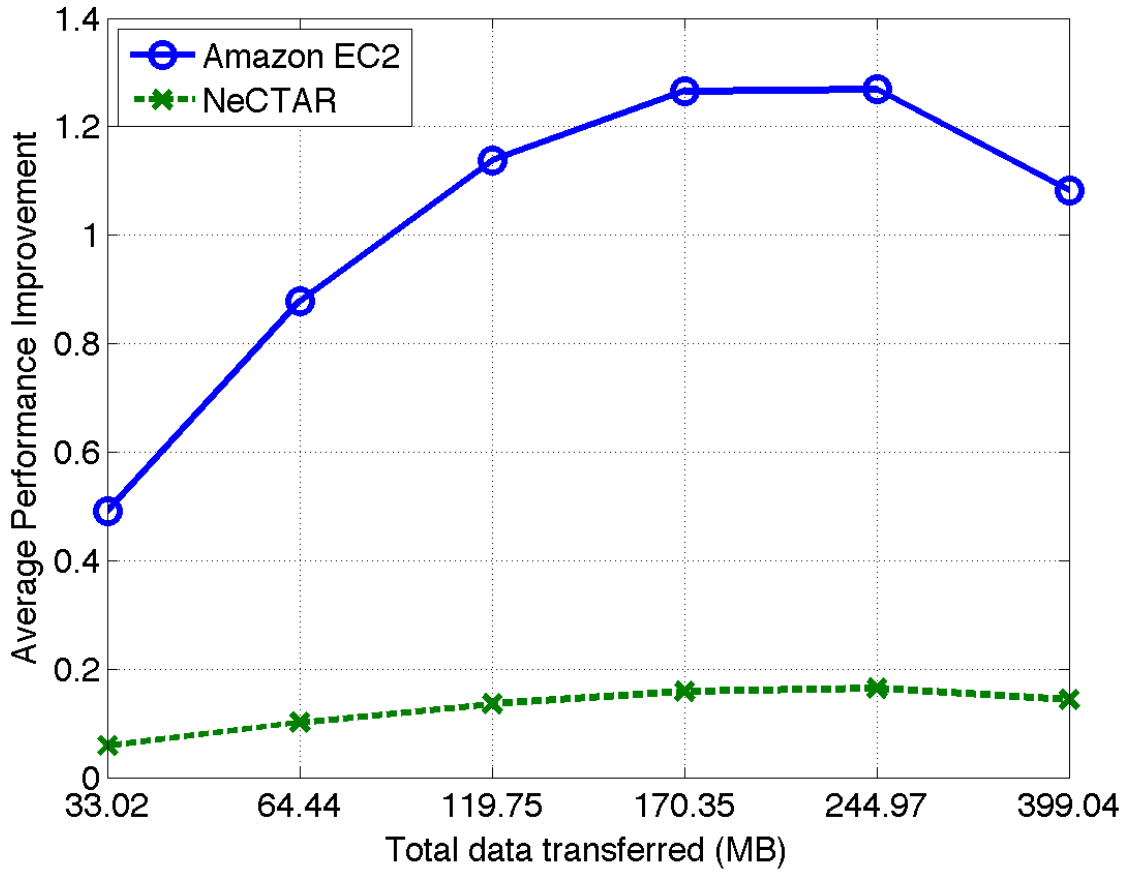
RESULTS

- Execution time of Workflows on Amazon's EC2
  - Hi-CPU Extra-Large instances 8-core, 17GB RAM
  - ap-southeast region (Singapore)



RESULTS

- Average performance improvement



Conclusions

- A new framework to implement data-centric workflows based on OMS
- Using decentralized service orchestration to bypass the bottleneck of centralized engine
- Substantially improvement the performance of data-centric workflows,
  - 20% on NeCTAR
  - 100% on EC2
- Future Work
  - Automate provisioning of Cloud resources for OMS-based workflows

Thank You