DICE: Quality-Driven Development of Data-Intensive Cloud Applications

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DICE Horizon 2020 Project
Grant Agreement no. 644869
http://www.dice-h2020.eu

Funded by the Horizon 2020
Framework Programme of the European Union

Overview and goals

- MDE often features quality assurance (QA) techniques for developers
- How should quality-aware MDE support data-intensive software systems?
  - Existing models and QA techniques largely ignore properties of data
  - Characterize the behavior of new technologies
- DICE: a quality-aware MDE methodology inspired by DevOps for data-intensive cloud applications

Motivation

- Software market rapidly shifting to Big Data
  - 32% compound annual growth rate in EU through 2016
  - 35% Big data projects are successful [CapGemini 2015]

- European call for software quality assurance (QA)
  - ISTAG: call to define environments *"for understanding the consequences of different implementation alternatives (e.g. quality, robustness, performance, maintenance, evolvability, ...)"*

- QA evolving too slowly compared to the trends in software development (Big data, Cloud, DevOps ...)

DataInc example

- DataInc is a small software vendor selling cloud-based environmental software

- DICEnv, a warning system for floods in rural regions
  - monitoring local environmental conditions
  - fetching precipitations data from satellite image stream

- DICEnv exploits Big Data technologies and cloud capacity for online water simulations and MapReduce for batch processing of historical data

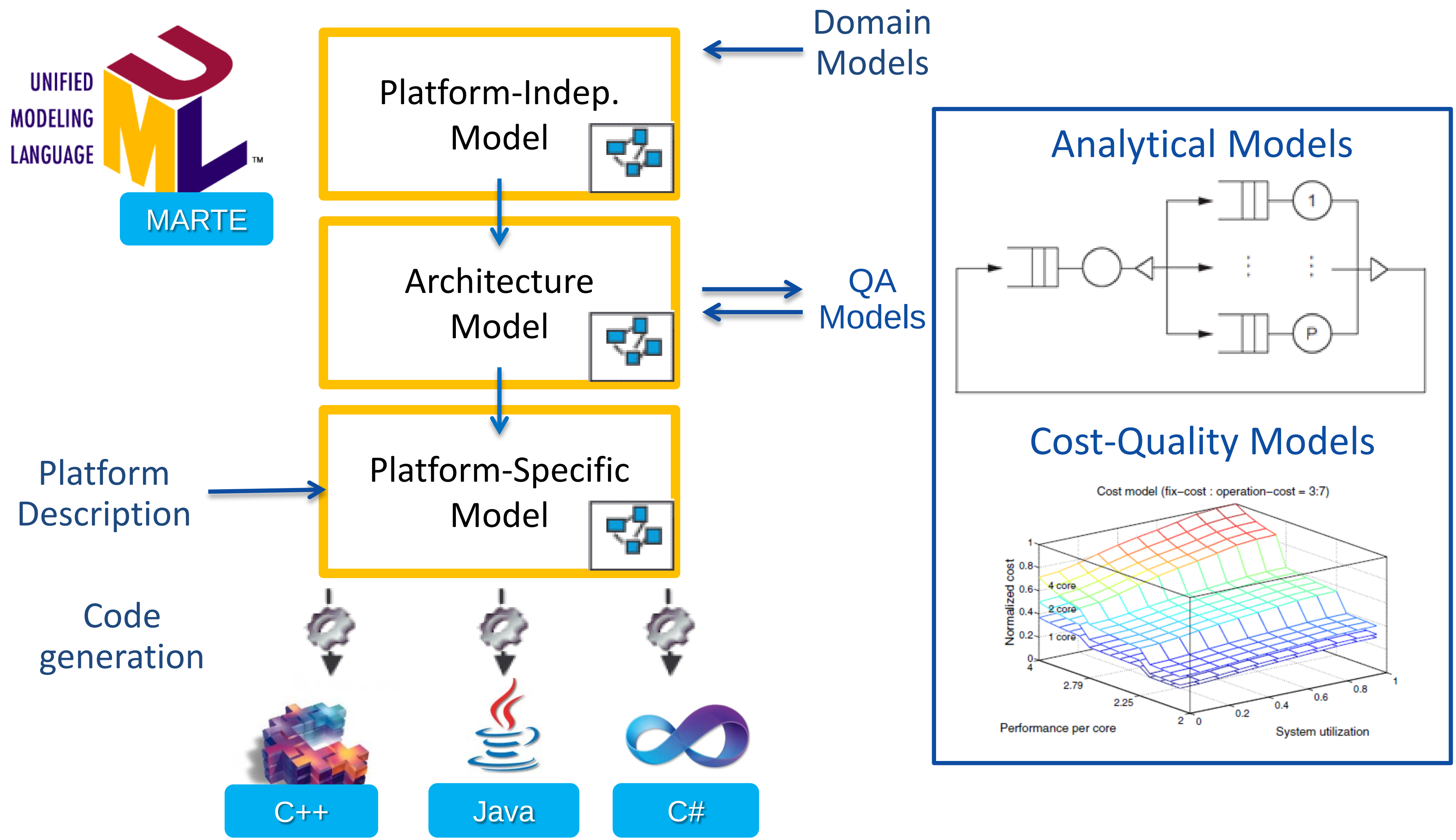
- DICEnv is a critical system:
  - is expected to remain up 24/7
  - should quickly ramp up data intake rates, as well as memory and compute capacities, to update more frequently the hazard management control room

DataInc example

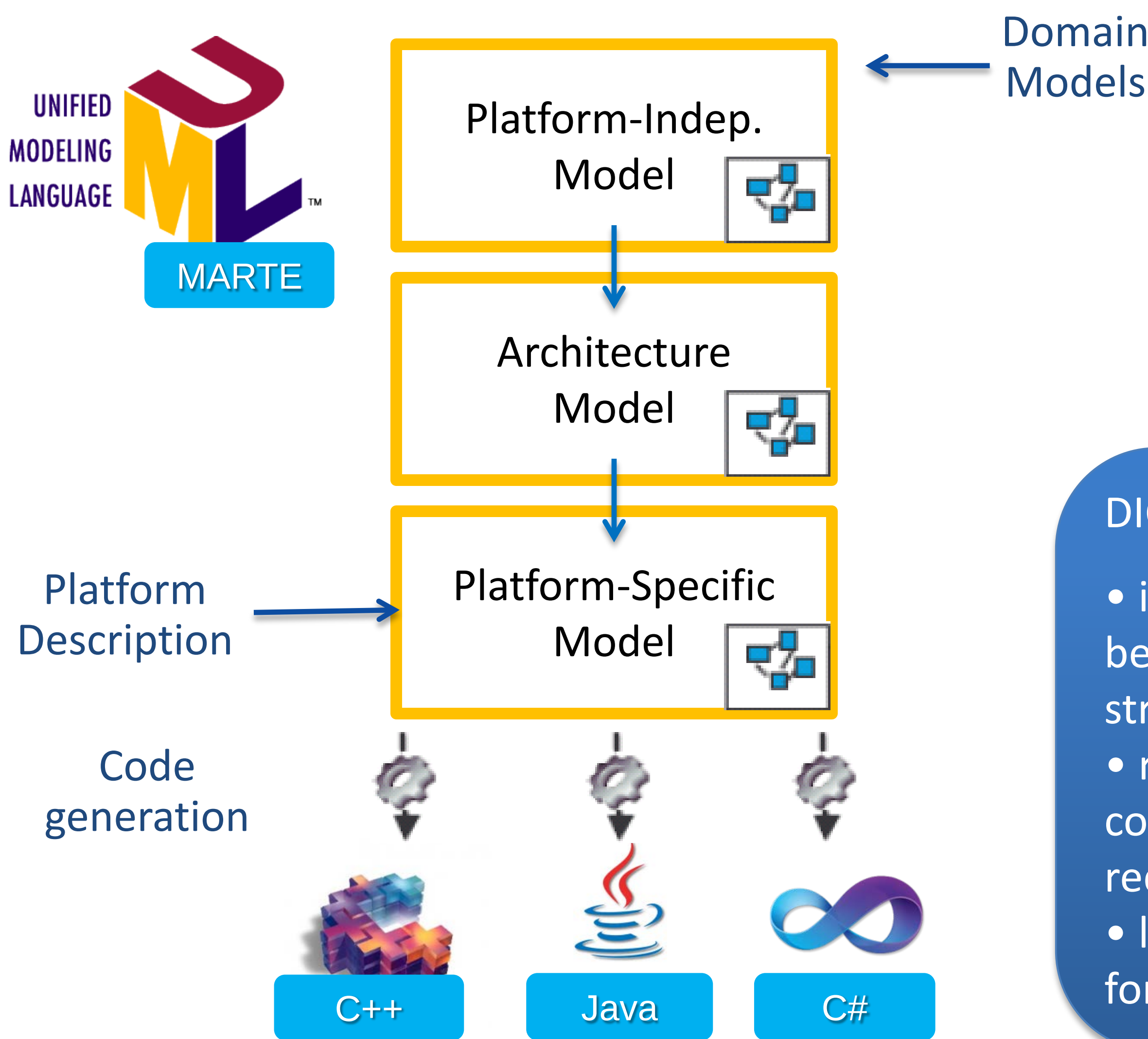
- The contract requires delivering an initial version of DICEnv within 3 months serving a small area, increasing coverage on a monthly basis

- Challenges:
  - How to implement a complex cloud application in such a short time?
  - How to satisfy all the quality requirements?
  - What architecture should be adopted?

Quality-Aware MDE Today



Quality-Aware MDE Today



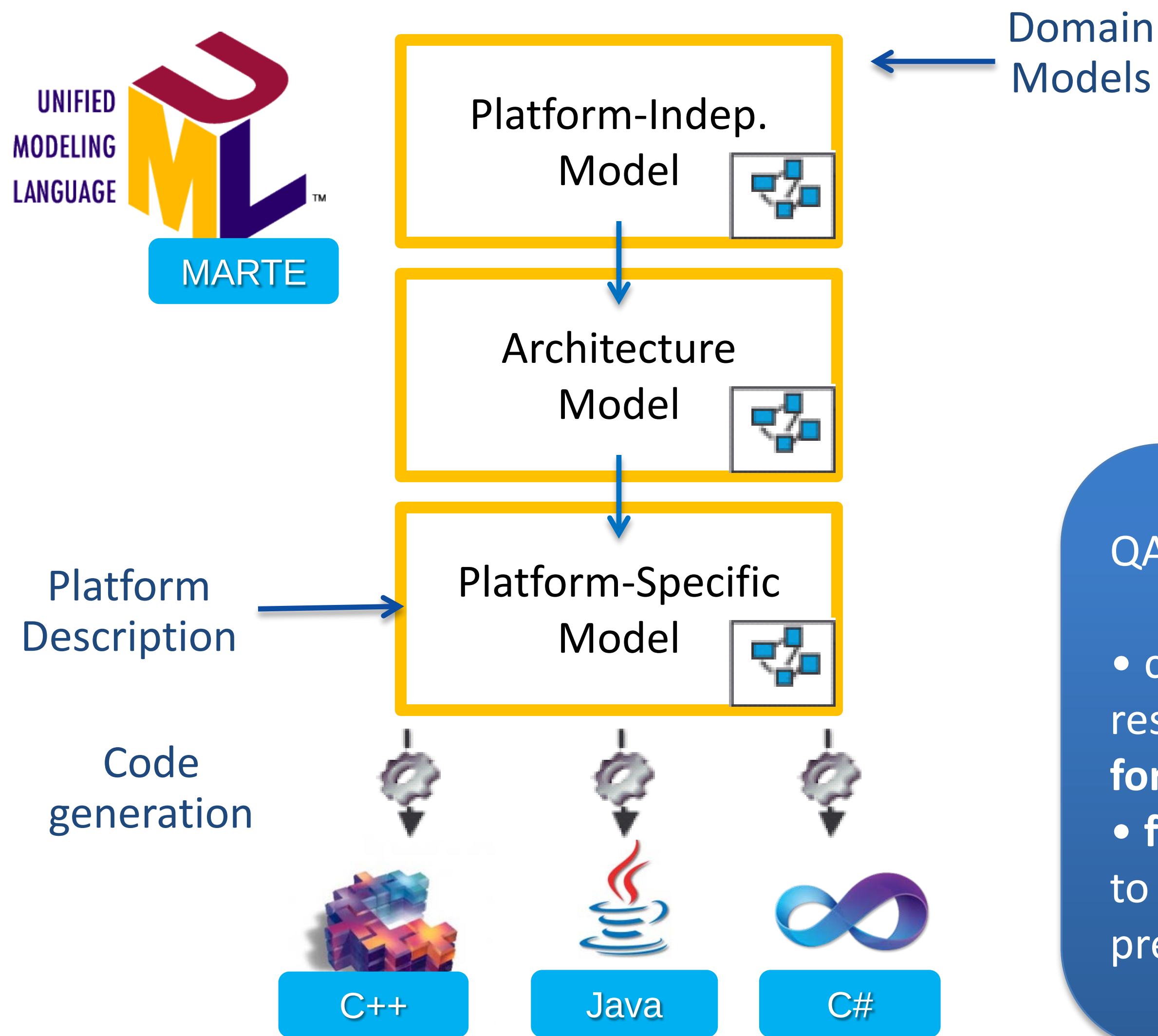
Issues PIM layer:

- *static characteristics of data*
- *dynamic characteristics of data*
- *data dependencies*

DICEnv modeling issues:

- individual dependencies between components and data streams
- relationships between compute and memory requirements
- lack of an explicit annotation for data characteristics

Quality-Aware MDE Today



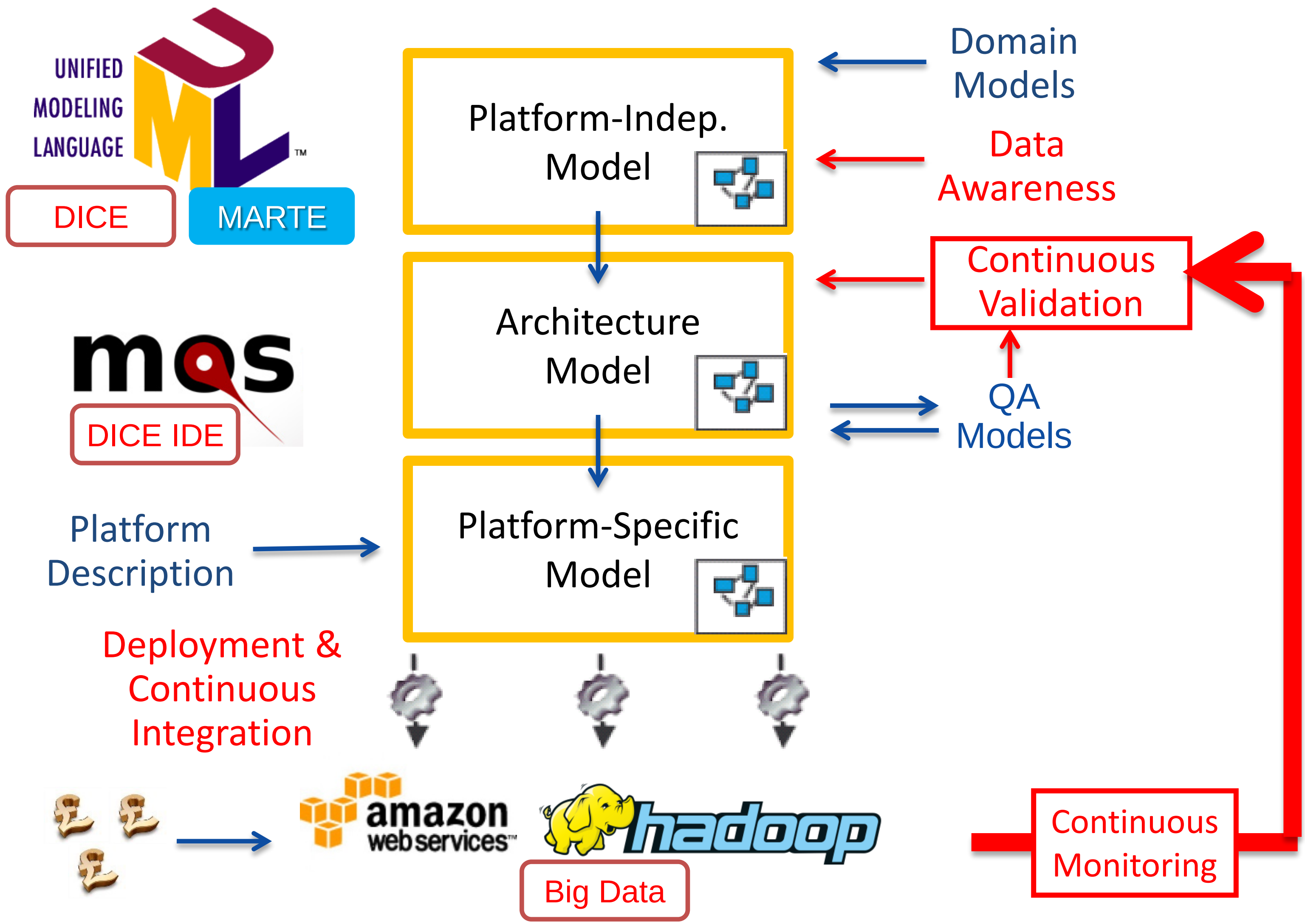
Issues at PSM layer:

- *heterogeneity* of Big Data technologies
- *automatic translation of PSM* models into deployment plans

QA tools limitations:

- contention at processing resources with **limited features for memory** consumption
- **fork and joining** are complex to be described analytically preserving tractability

An Holistic Approach: DICE



Embracing DevOps

- Software development process is evolving
  - Developer: “I want to change my code”
  - Operator: “I want systems to be stable”
    - ...but code changes are the cause of most instabilities!
- DevOps closes the gap between Dev and Ops
  - Lean release cycles with automated tests and tools
  - Deep modelling of systems is the key to automation

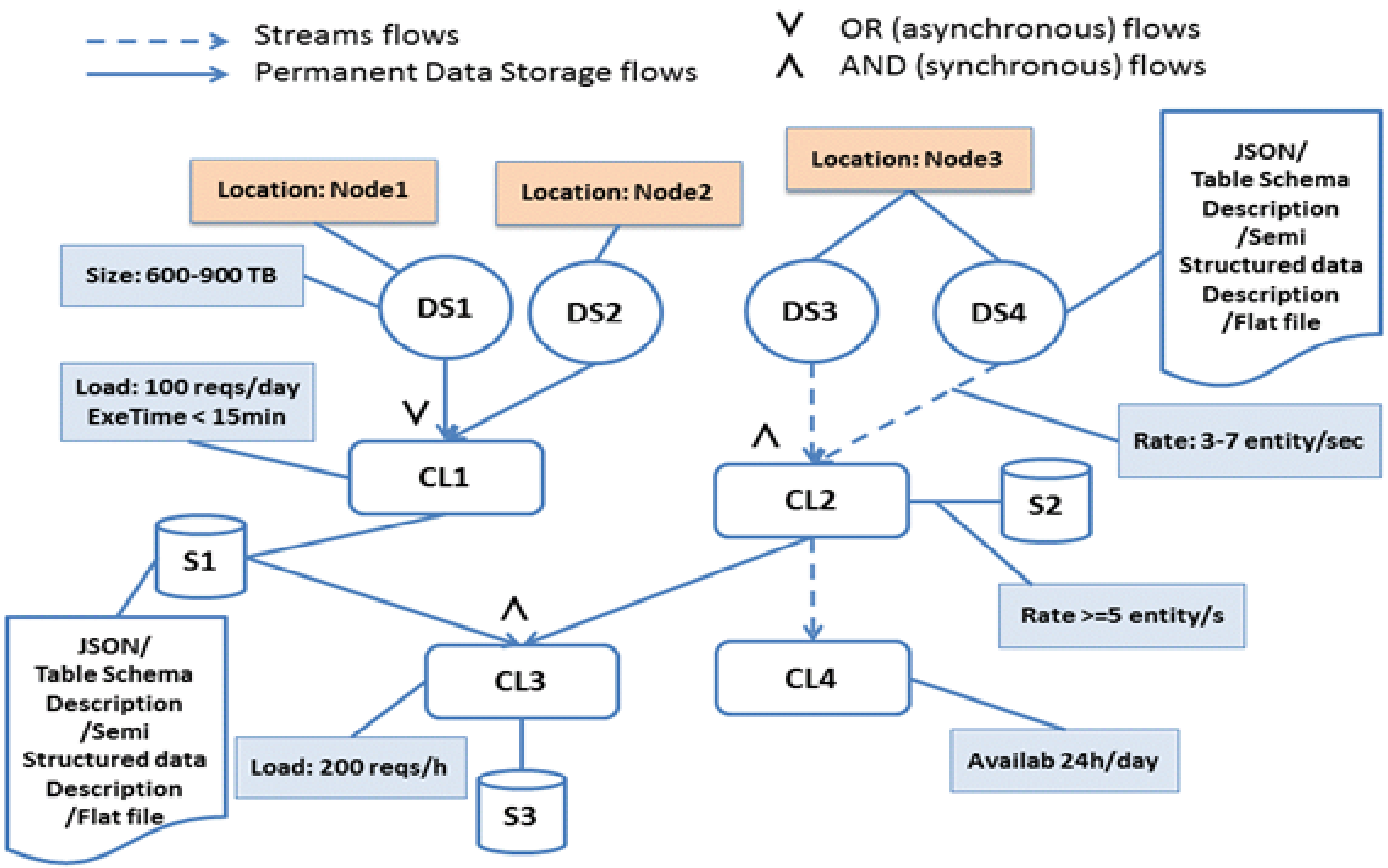
Embracing DevOps

- QA must become lean as well
  - Continuous quality checks and model versioning
- Modelling of the operations
  - Dev needs awareness of infrastructure and costs
- Continuous feedback
  - Forward and backward model synchronisation
  - Tracking of self-adaptation events (e.g. auto-scaling)
- Big data coming from continuous monitoring
  - QA has its own Big data, use machine learning?

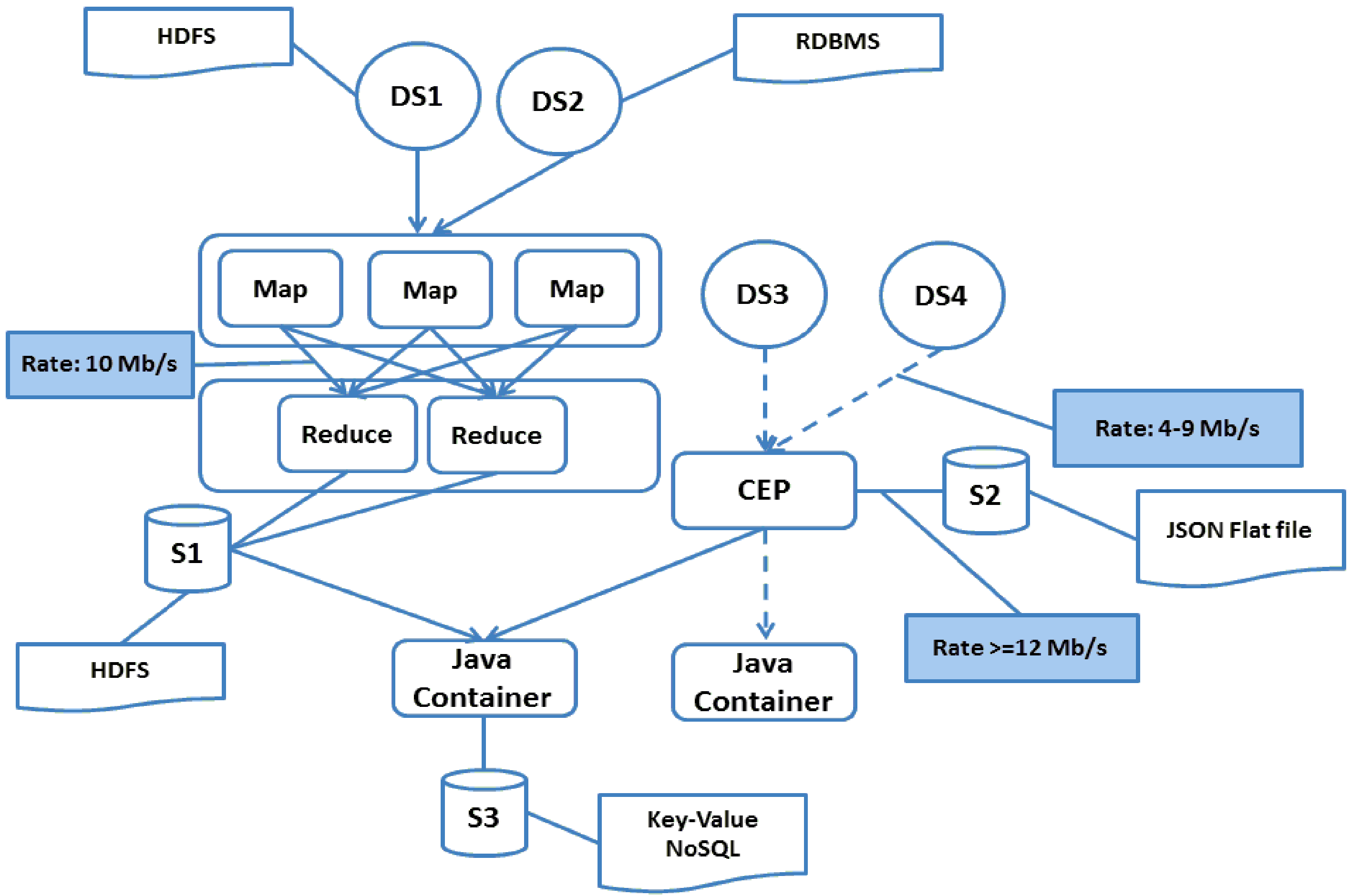
Benefits

- Tackling skill shortage and steep learning curves
  - Data-aware methods, models, and OSS tools
- Shorter time to market for Big Data applications
  - Cost reduction, without sacrificing product quality
- Decrease development and testing costs
  - Select optimal architectures that can meet SLAs
- Reduce number and severity of quality incidents
  - Iterative refinement of application design

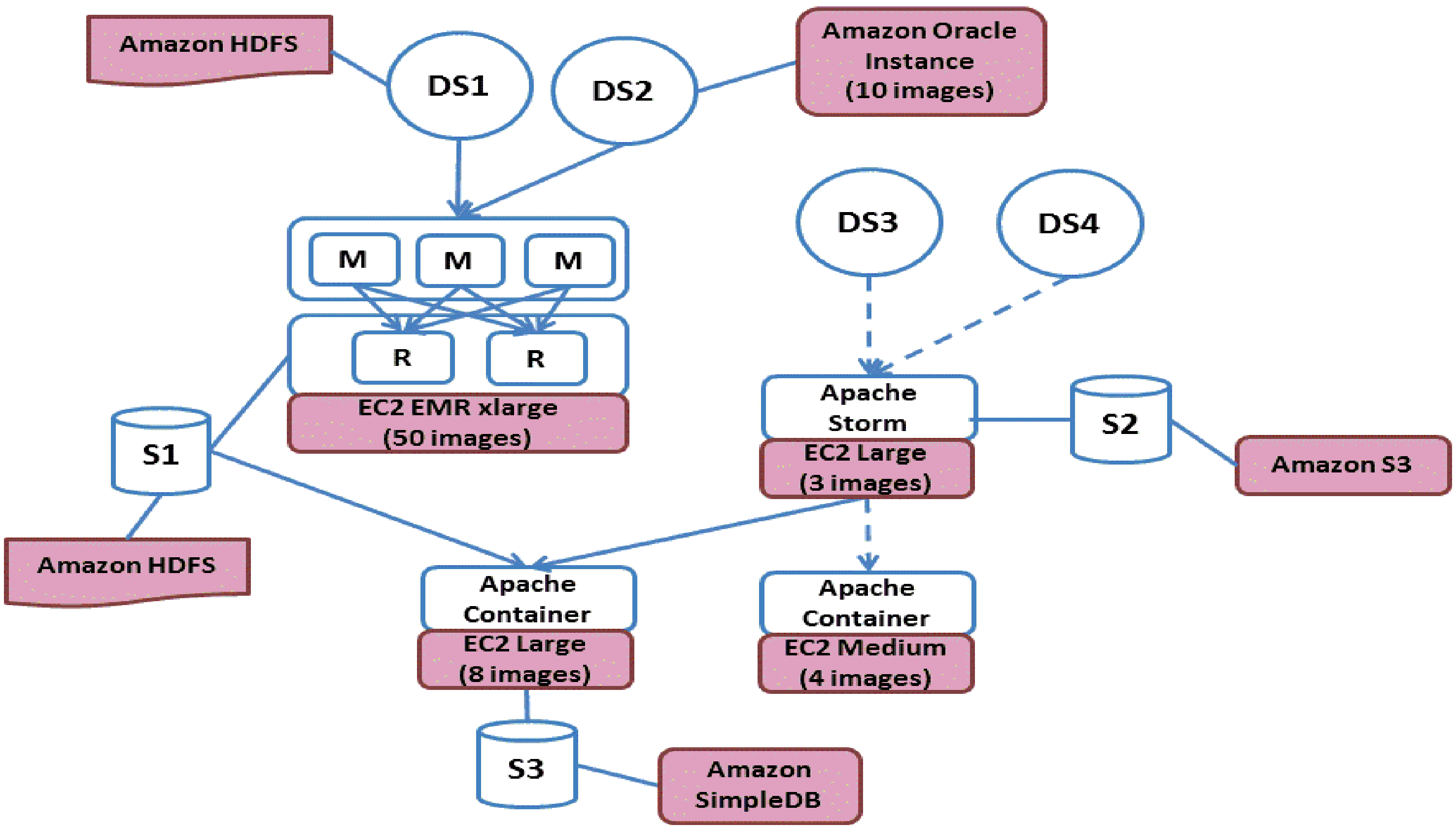
DICE Platform Independent Model (DPIM)



DICE Platform and Technology Specific Model (DTSM)



DICE Platform, Technology and Deployment Specific Model (DDSM)



DICE Profile: PIM Level

- Functional approach to data to be expanded
  - Data dependencies
    - graph relationships between data, archives and streams
- QA focuses on quantitative aspects of data
  - Static characteristics of data
    - volumes, value, storage location, replication pattern, consistency policies, data access costs, known schedules of data transfers, data access control / privacy, ...
  - Dynamic characteristics of data
    - cache hit/miss probabilities, read/write/update rates, burstiness, ...

DICE Profile: PSM Level

- Need for technology-specific abstractions
  - Hadoop: Number of mappers and reducers , ...
  - In-memory DBs: Peak memory and variable threading
  - Streaming: merge/split/operators, networking, ...
  - Storage: Supported operations, cost/byte , ...
  - NoSQL: Consistency policies , ...
- Generation of deployment plan
  - Proposed Chef + TOSCA extension
- Interest is both on private and public clouds

DICE QA: Quality Dimensions

- Reliability
  - Availability
  - Fault-tolerance
- Efficiency
  - Performance
  - Time behaviour
  - Costs
- Safety
  - Risk of harm
  - Privacy & data protection

DICE QA: Tools

- *Discrete-event simulation*: assess reliability and efficiency in Big Data applications, accounting for stochastic evolution of the environment
  - stochastic Petri nets or queueing networks, rely on simulation

- *Formal verification tools*: assess safety risks in Big Data applications, e.g. find design flaws causing order and timing violations in message and state sequences
  - temporal logic formulae and bounded model checking, satisfiability modulo theories solvers
  - quantifier-elimination techniques to extend temporal logic-based verification

DICE QA: Tools

- *Architecture optimization tool*: find architectural improvements to optimise costs and quality
  - decomposition-based analysis approach
  - resort to fluid approximation of stochastic models

- *Feedback analysis*: automated extraction from the monitored data of key parameters required to define simulation and verification models
  - extract model parameters through log mining and statistical estimation methods
  - breakdown resource consumption into its atomic components on the end-to-end path of requests

DICE Project http://www.dice-h2020.eu

- Horizon 2020 Research & Innovation Action
  - Quality-Aware Development for Big Data applications
  - Feb 2015 - Jan 2019, 4M Euros budget
  - 9 partners (Academia & SMEs), 7 EU countries