Guaranteed Latency Applications in Edge-Cloud Environment

http://d3s.mff.cuni.cz

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faculty of mathematics and physics

Modern cyber-physical systems

- Combine distributed embedded devices with computation in cloud
- Applications:
  - Smart agriculture,
  - Smart power grid,
  - Smart traffic, …

- Include thousands to millions of devices
- Inclusion of cloud makes possible advanced data analysis and decision-making
  - making the system “smarter”

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Real-time requirements

- Interaction with the physical world
  - Leads to the presence of the real-time requirements
    - e.g. a real-time video stream has to be processed without any significant delay
- Interaction with the cloud
  - Happens even inside the real-time tasks running on embedded devices
    - The cloud has to participate in overall real-time guarantees
      - No way to ensure these guarantees is provided by the cloud software

Existing approaches

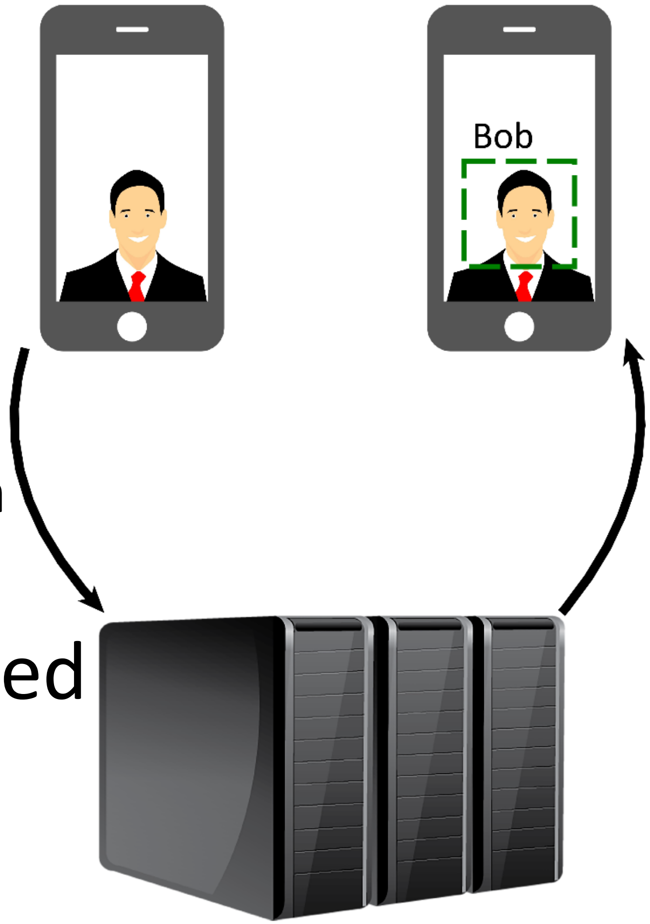
- Existing approaches generally try to reduce the communication latencies
  - By bringing the cloud closer to user
  - By caching the data
  - By prediction
- All these approaches still work on best-effort
  - i.e. no real-time guarantees provided

Our approach

- Combining edge-cloud processing with runtime performance awareness
- Real-time guarantees are provided by:
  - Pre-assessing the application
  - Monitoring the application performance
  - Predicting the application performance based on historical observations
- Cloud-centric control of applications
  - Traditional declarative deployments
    - Extended with timing requirements specification

Running example

- An augmented reality application
  - A mobile phone application
  - A processing part in the cloud
    - Analyzes the video stream from clients
    - Sends back the augmenting information
      - e.g. recognized faces
- The information has to be displayed with minimum delay
  - Even better, with a guaranteed communication latency



Structure of the approach

- Q1: Specification of the real-time guarantees
  - In line with existing practices
  - Establishing a verifiable contract
- Q2: Assessment of cloud applications
  - To determine whether the response time can be guaranteed
  - Performed automatically
- Q3: Providing guarantees at runtime
  - In face of changing conditions
    - Background load
    - User mobility

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Q1: Real-time guarantees specification

- Traditional declarative specification of microservices
  - + Measurement probes specification
  - + Real-time requirements specification
- Probe – a function that performs a performance test
  - Does not take any inputs
  - Can be measured at runtime
  - Strongly correlates with the operation that needs to be guaranteed
- Timing requirements are specified over the probes
  - In contrast to real operations

Q1: Extended deployment descriptor

- Our implementation extends Kubernetes deployment specification
  - Contains a specification of timing requirements
    - "**below X ms in Y% of cases**"
    - Defined over probes
      - Also a part of the extended descriptor


```
kind: Deployment
metadata:
  name: recognizer-deployment
  labels:
    app: recognizer
spec: # micoservices specification
  template:
    metadata:
      labels:
        app: recognizer
  spec:
    containers:
    - name: recog
      image: d3srepo/recog
      ports:
      - containerPort: 7777
probes: # probes
- name: recognize
timingRequirements: # timing requirements
- name: recognize limit
  probe: recognize
  limits:
  - probability: 0.999
    time: 50 # Max. 50ms in 99.9% cases
  - probability: 0.99
    time: 30 # Max. 30ms in 99% cases
```


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Q2: Assessment of an application

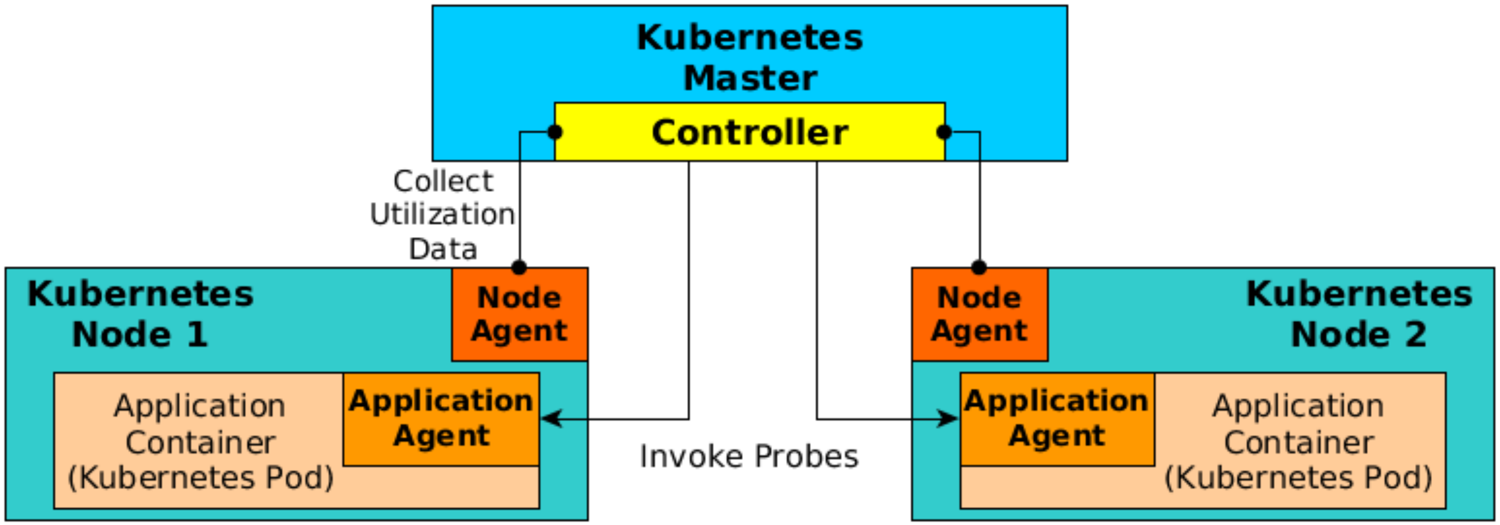
- Performed before the actual deployment of the application
- Verifies feasibility of the timing requirements
  - Informs the developer whether the application can be admitted and on what terms
- The probes are invoked many times in this process
  - Each invocation collects data about the probe's behavior

Q2: Measurement

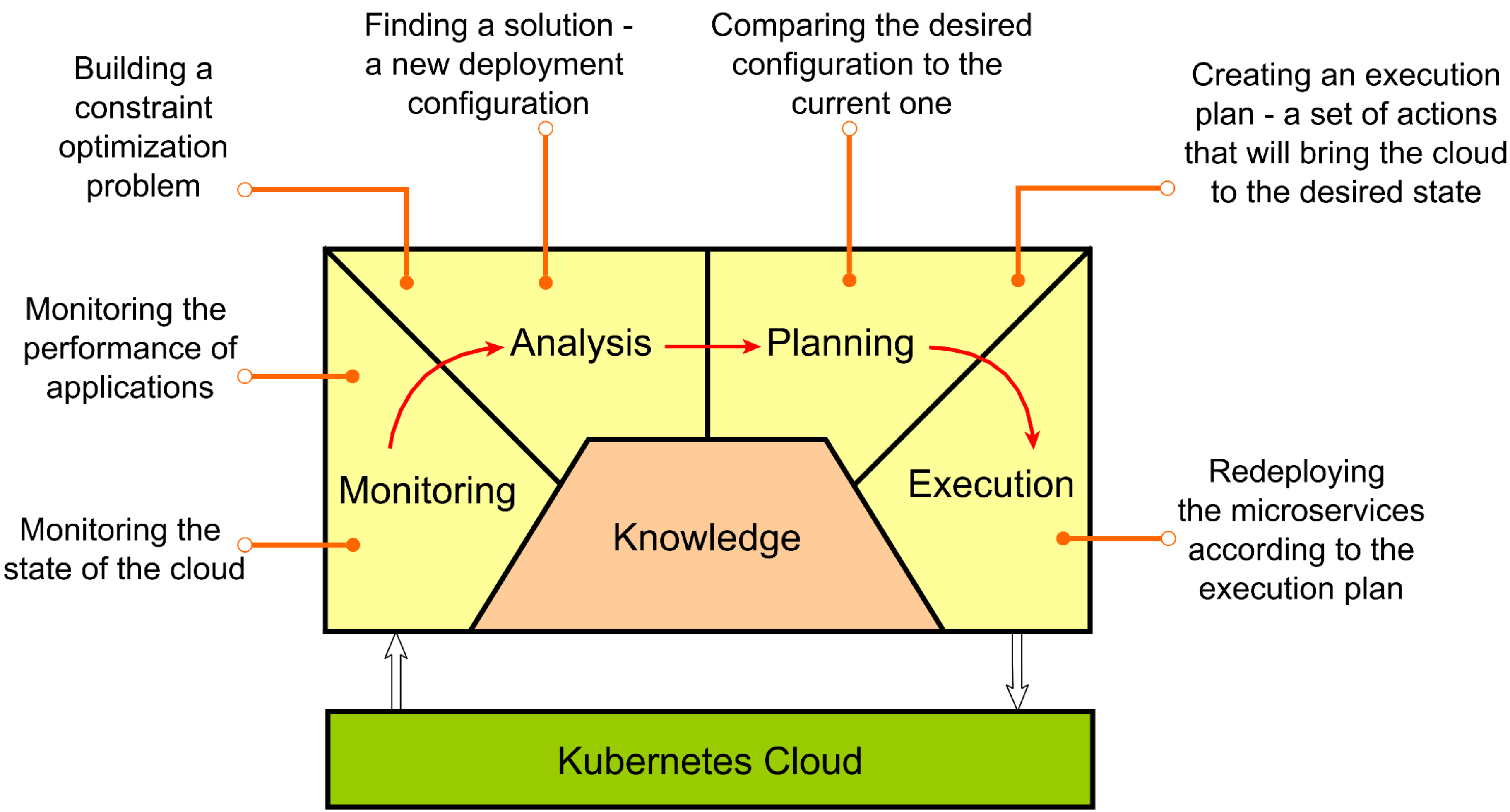
- Application performance is measured with different background workloads
  - IO-intensive, CPU-intensive, memory-intensive, …
  - Gives us estimates on how different applications impact each other
- System counters are collected in the process
  - Instruction count, cache miss count, IOPS, …
  - Allows us to categorize probes by performed computation type
- Gradually, this builds knowledge about application performance
  - Used in what-if analysis about the impact of different applications on each other
    - The precision of the analysis grows with time

Q3: Providing the real-time guarantees

- To have a control over the deployment of applications, we provide the ***Controller***
  - An intermediary between the user and the cloud
  - Collects information from the nodes via *node agents*
  - Controls the probe invocation via *application agents*
  - Responsible for execution of the self-adaptation loop



Q3: Self-adaptation loop



Summary

- Our approach provides statistical guarantees on the response time of the edge-cloud applications
- Timing requirements are specified directly as a part of the deployment specification
- Guarantees are kept in changing conditions
  - Thanks to performance awareness and adaptation
- Key ideas of the approach:
  - Specification of the requirements over the pre-defined probes
  - Automatic pre-assessment of the application
  - Building a queryable knowledge model for improving adaptation decisions

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Current and future work

- Our experiments show that applications can be successfully categorized based on resource utilization
- Currently, our framework includes:
  - A control architecture over K8S
  - Prototypes of all of its main components

Thanks!