

# Monitoring and Communication in Self-adaptive Systems using Control Loops

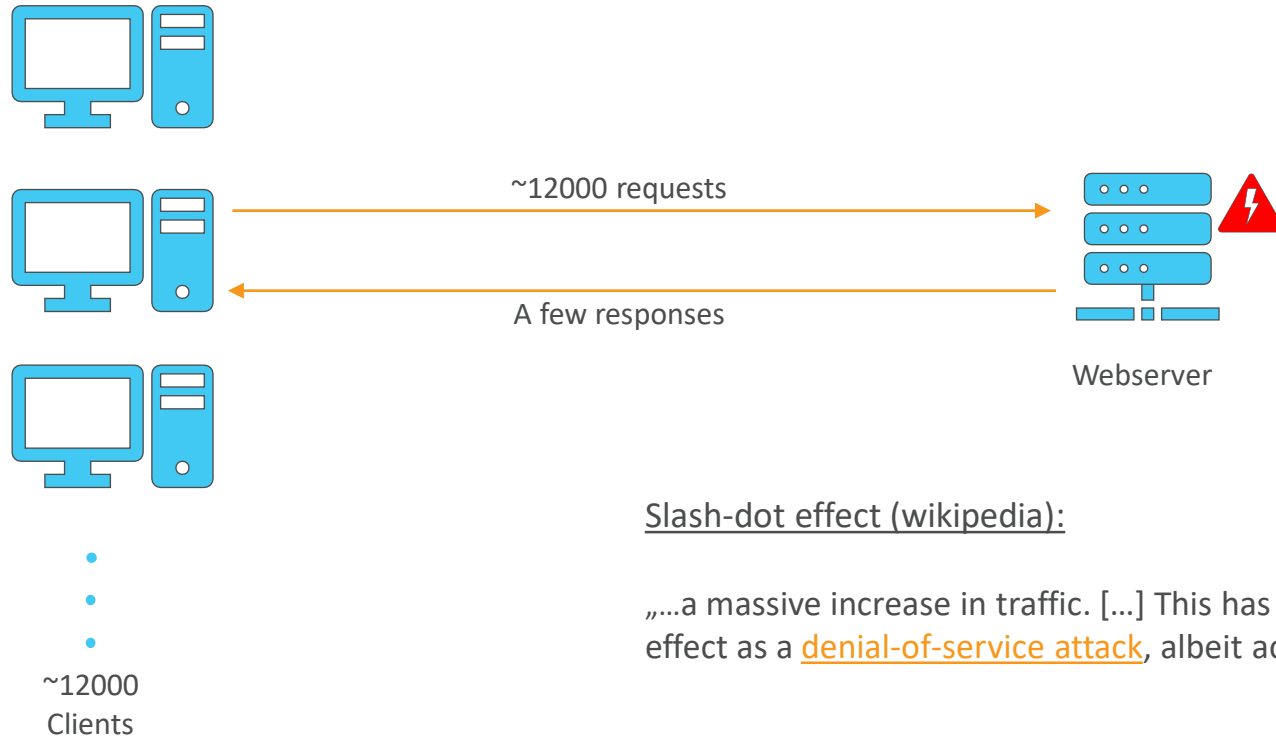
Ilja Shmelkin

1<sup>st</sup> TAB-Talk, 07.12.2020

# One possible scenario...



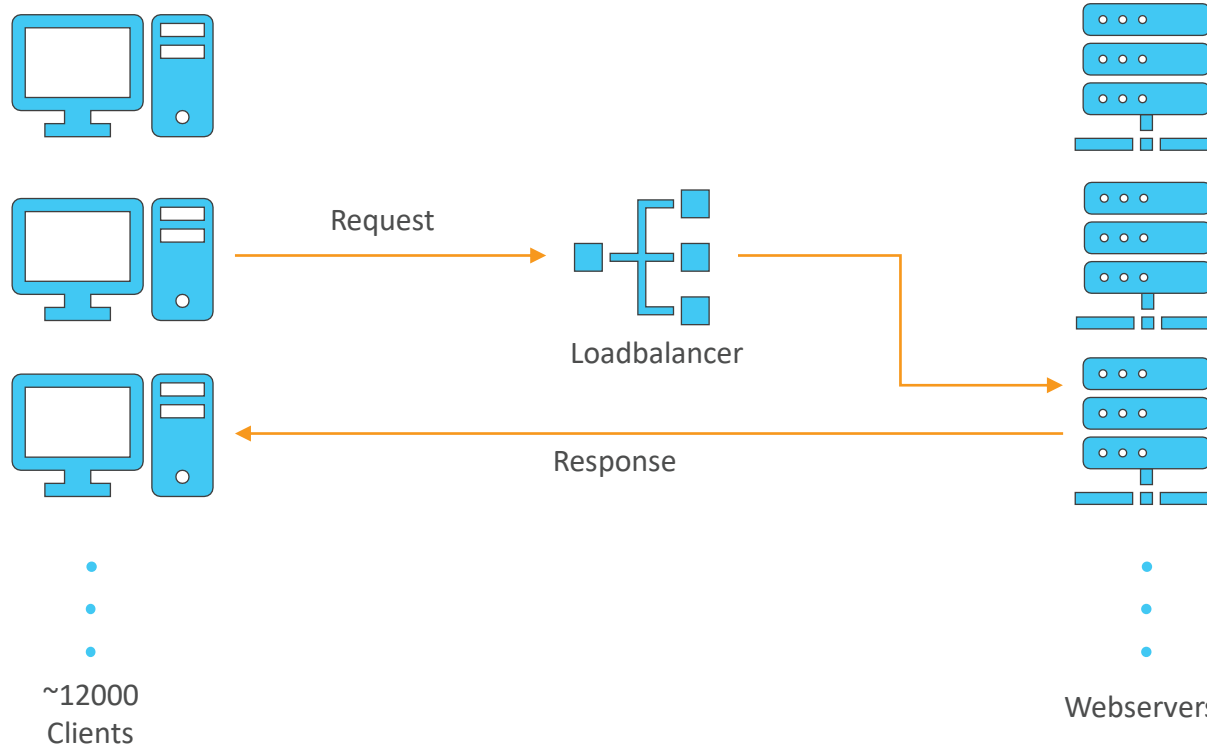
# One possible scenario...

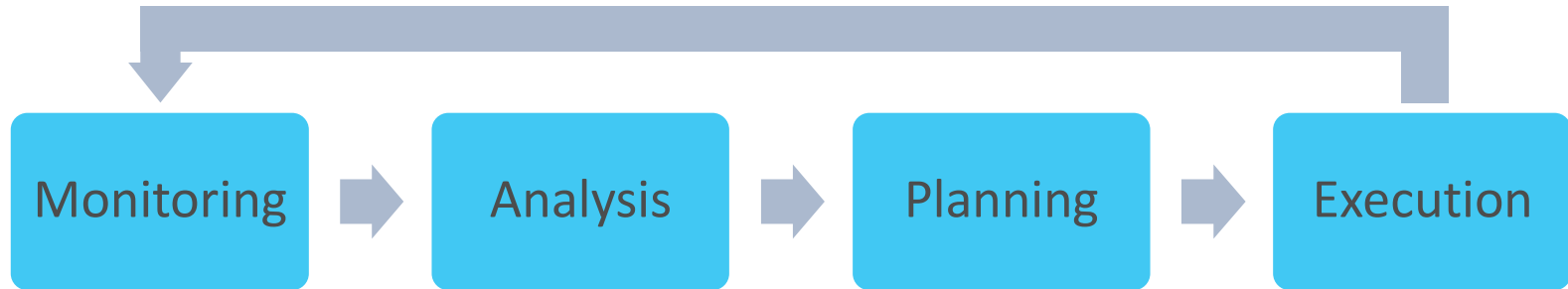


Slash-dot effect (wikipedia):

„...a massive increase in traffic. [...] This has the same effect as a denial-of-service attack, albeit accidentally.”

# One possible scenario...





- Monitor CPU usage of web-servers
- Is CPU usage normal or abnormal?
- Fetch strategy to correct CPU usage (e.g., reduce/increase number of web-servers)
- Execute commands

Thesis contributions ([SEAMS 2020](#), [doctoral symposium](#)):

- Provide adaptation performance enhancement through proper usage of monitoring knowledge
- Provide best practice communication methods, platforms and protocols for self-adaptive systems that rely on the MAPE control loop
- Find strategies for synchronization between components of the same type in distributed scenarios

## „CORRECT COMMUNICATION“ IS OFTEN PRESUPPOSED:

- „.... furthermore, the connections between the feedback loop model and external elements needs to **ensure correct communication.**“

## THE NEED FOR STANDARDIZED COMMUNICATION WAS EXPRESSED MULTIPLE TIMES:

- „Second, **we do not consider** the distribution of the MAPE components and **the communication resulting from actual deployment** based on a particular network topology and supporting communication infrastructure (message oriented, publish-subscribe, etc.)“
- „**Future research should focus on the specific protocols used for communication** between the MAPE components (for example, push-pull, request-reply, negotiation)“
- „So far, the research community has focused on standardizing the notification interfaces of sensors and effectors of managed subsystems, **but ignored communication within the MAPE loop.**“
- „Our position of making the decentralization of control loops explicit underlines **the need for standardizing the interactions between the MAPE loop components.**“

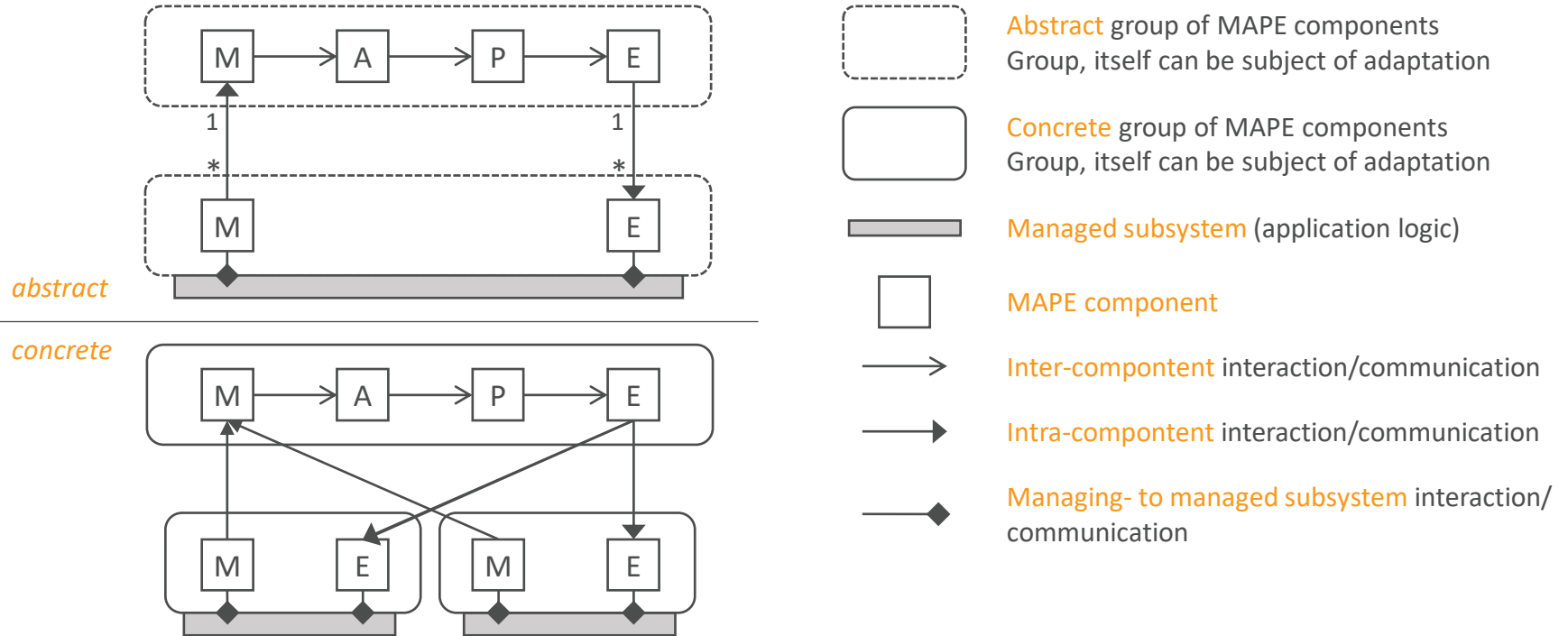
# Research questions

1) HOW CAN WE DEFINE **UNIFORM COMMUNICATION INTERFACES AND PROTOCOLS** FOR DISTRIBUTED SELF-ADAPTIVE SYSTEMS THAT RELY ON THE MAPE CONTROL LOOP?

2)

3)

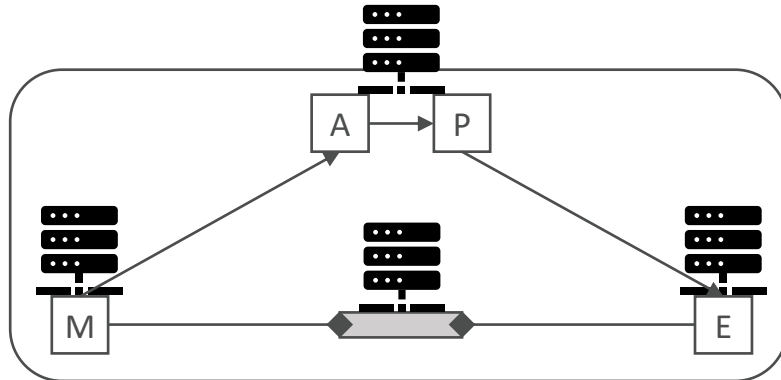
# MAPE-Patterns (by Weyns et al.)





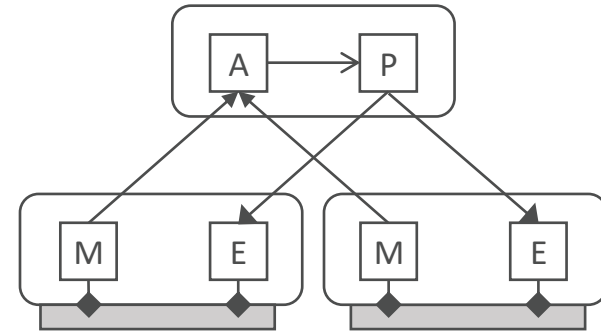
## Distribution in control loops

- DEPLOYMENT OF SELF-ADAPTATION LOGIC ON DIFFERENT NODES/SERVERS
- NODES ARE CONNECTED VIA COMPUTER NETWORK

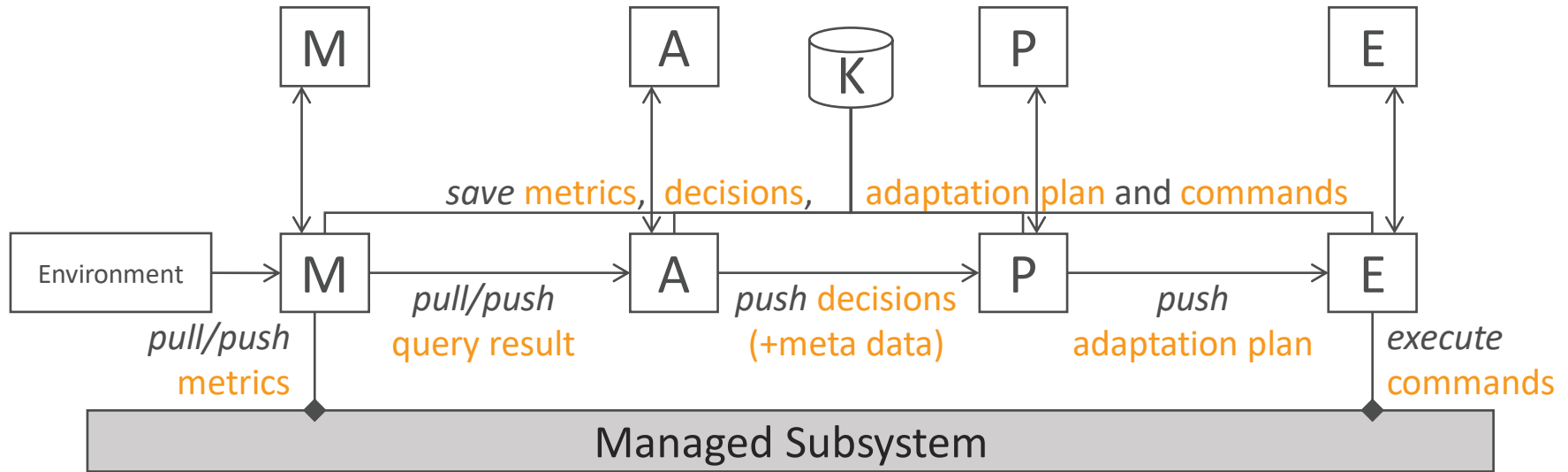


## Decentralization in control loops

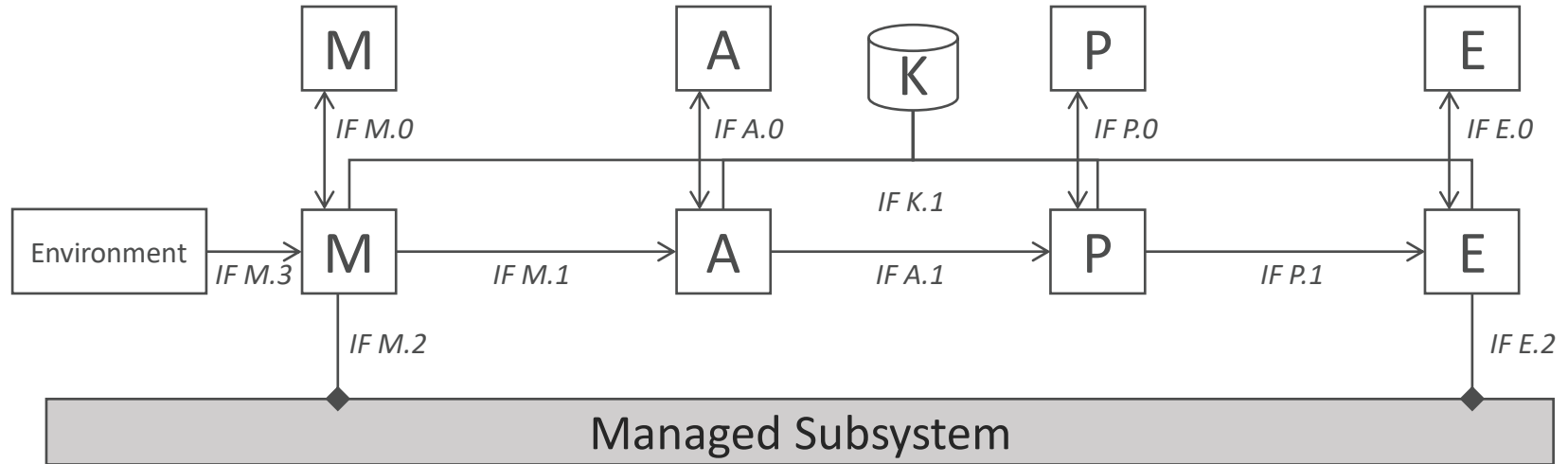
- PARTS OF SELF-ADAPTATION LOGIC ARE EITHER CENTRALIZED OR DECENTRALIZED
- ANALYZE AND PLANNING ARE CENTRALIZED IN THE FOLLOWING EXAMPLE



# Communication in MAPE-K control loops



# MAPE-K Interface Descriptions



# Control Loop Communication Protocol Requirements

- 1) REQUESTED TRANSFER OF DATA (PULL)
- 2) UNREQUESTED TRANSFER OF DATA (PUSH)
- 3) BULK-TRANSFER/STREAMING OF DATA TO TRANSMIT METRICS AND PERFORMANCE DATA
- 4) SYNCHRONIZATION BETWEEN INDIVIDUAL COMPONENTS
- 5) SECURE ENCRYPTION AND AUTHENTICATION MECHANISMS

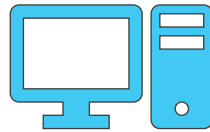
MAYBE MORE IN FUTURE..., DISCUSSION VERY WELCOME!

# Simple Network Management Protocol

## SNMP Agent

- Runs on a managed device
- read/read-write access
- Can be basically any device (router, switch, VOIP-devices, arbitrary linux-machine, arbitrary windows-machine and many more)

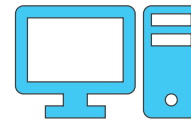
## SNMP Agent



notify

(ACK)

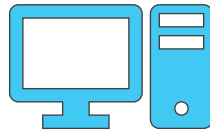
## SNMP Manager



## SNMP Manager

- Runs on a managing device
- Holds MIB (management information base)
- Holds main processing and memory resources
- One or multiple can be present in a network

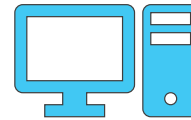
## SNMP Agent



request

metrics

## SNMP Manager



**IN PRACTICE: AGENTS AND MANAGERS MOSTLY RUN THE EXACT SAME SNMP-SOFTWARE**

# Simple Network Management Protocol



## TRAP (IF {M.0, M.3, A.1, P.1, K.1})

- Asynchronous notification from agent to manager.

## INFORM (IF {M.0, M.3, A.1, P.1, K.1})

- Asynchronous notification from agent to manager with acknowledgement.

## GET-REQUEST (IF {M.0, M.1, M.2, M.3, A.0, P.0, E.0, E.2, K.1})

- A manager-to-agent request to retrieve the value of a variable or list of variables.

## GETNEXT-REQUEST (IF {M.0, M.1, M.2, M.3, A.0, P.0, E.0, E.2, K.1})

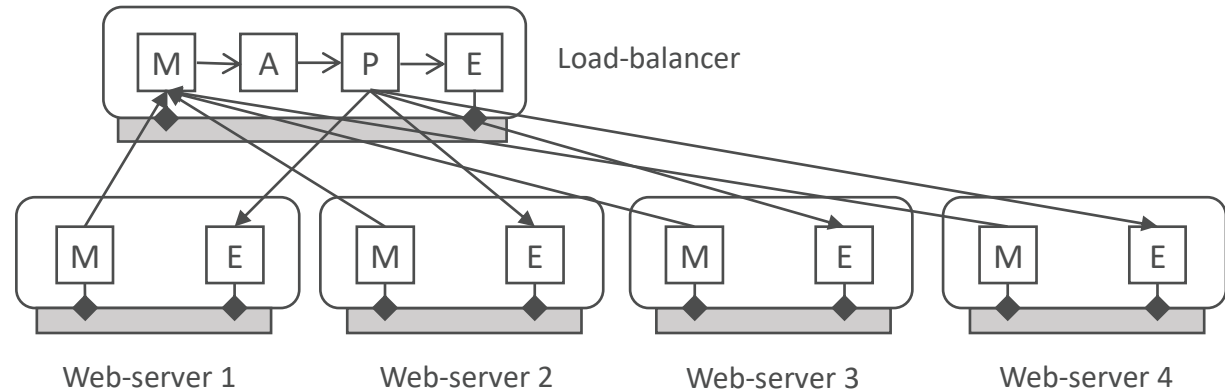
- A manager-to-agent request to discover available variables and their values (next value in lexicographically order)

## GETBULK-REQUEST (IF {M.0, M.1, M.2, M.3, A.0, P.0, E.0, E.2, K.1})

- A manager-to-agent request for multiple iterations of *GetNextRequest*.

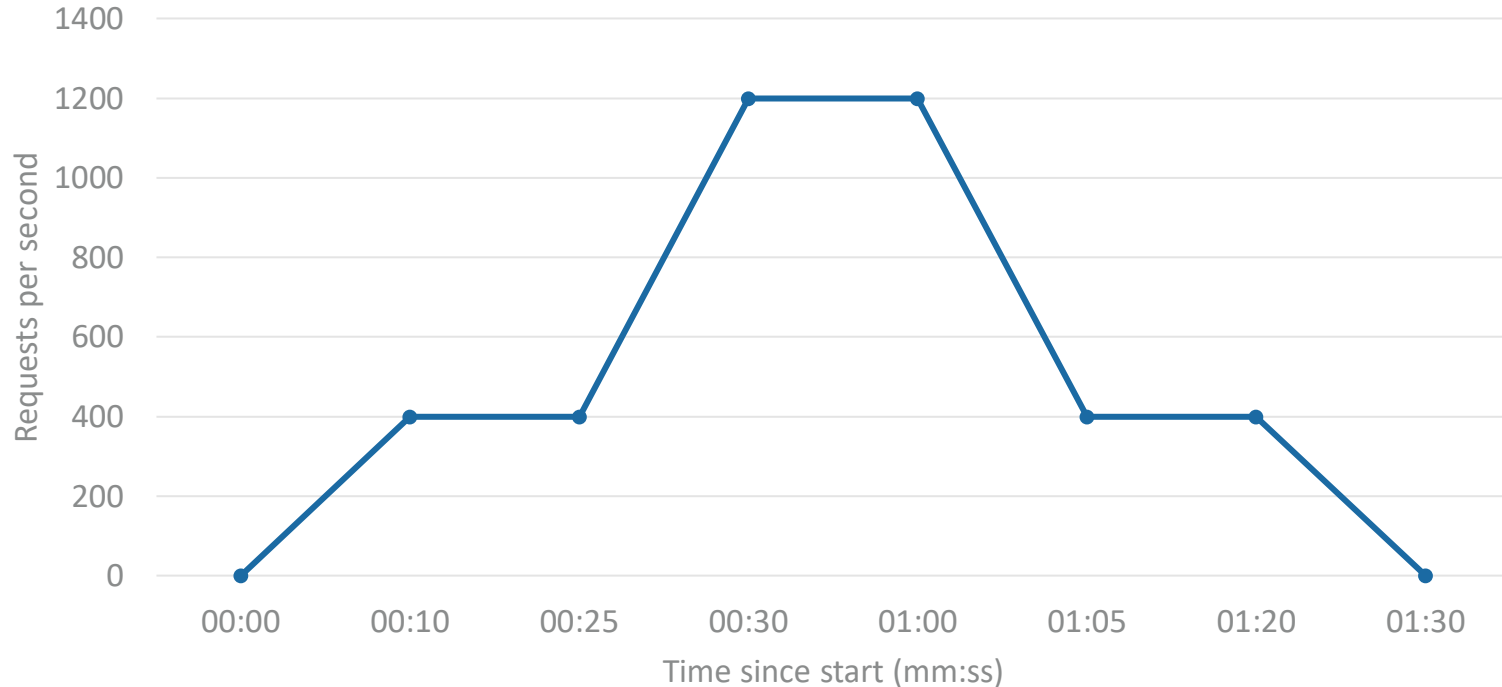
# Re-implementation of Znn.com (Cheng et al.)

- 10 CLIENT MACHINES TO ARTIFICIALLY PUT LOAD ON THE INFRASTRUCTURE
  - 16 CPU cores á 2.4GHz
  - 16 GB RAM
- 1 LOADBALANCER MACHINE
  - 4 CPU cores á 2.4GHz
  - 4 GB RAM
- 4 WEBSERVER MACHINES
  - 1 CPU core á 2.4GHz
  - 2 GB RAM



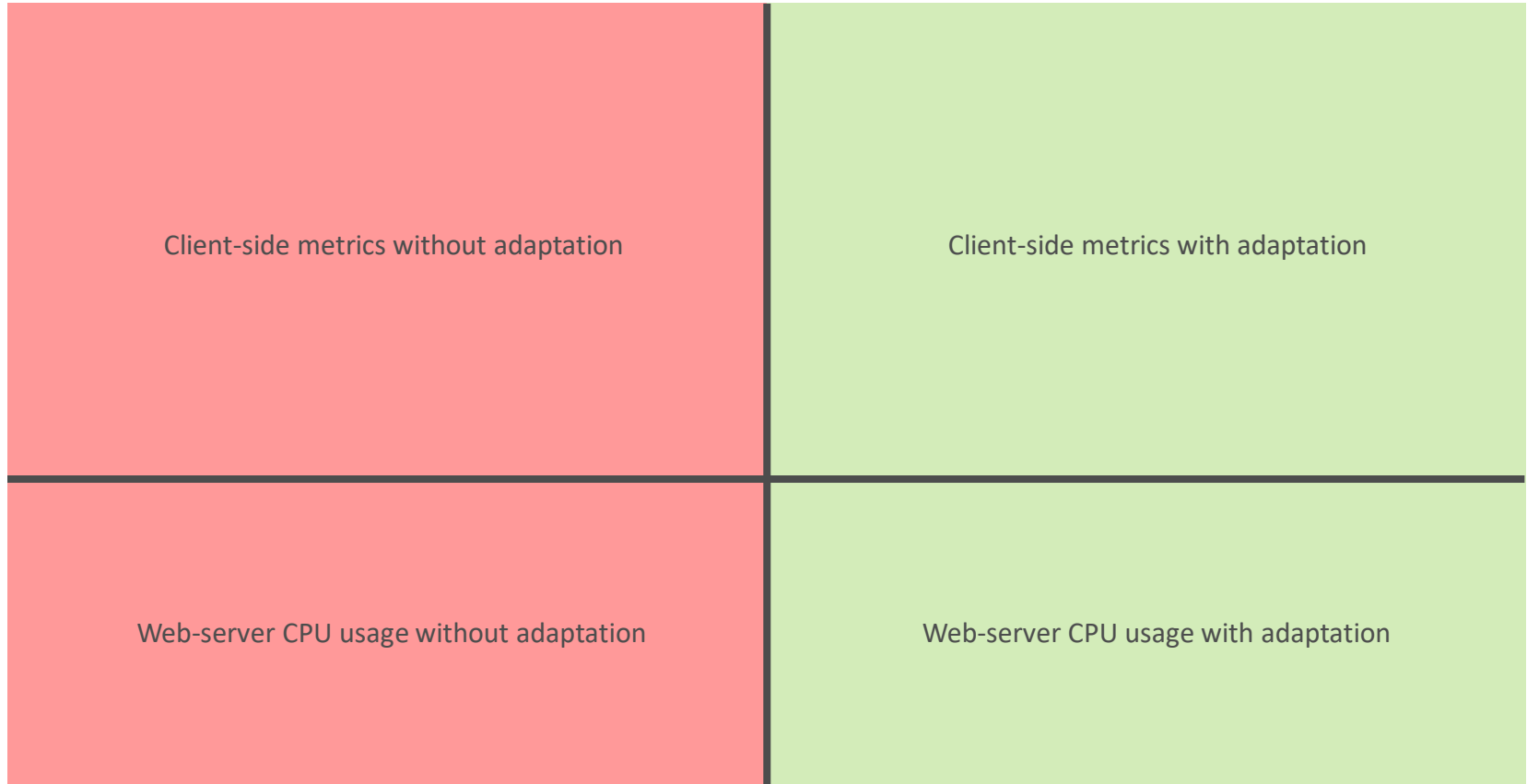
# Slash-dotting the Self-adaptive System

APACHE JMETER IS USED IN THE CLIENT CLUSTER (10 MACHINES)

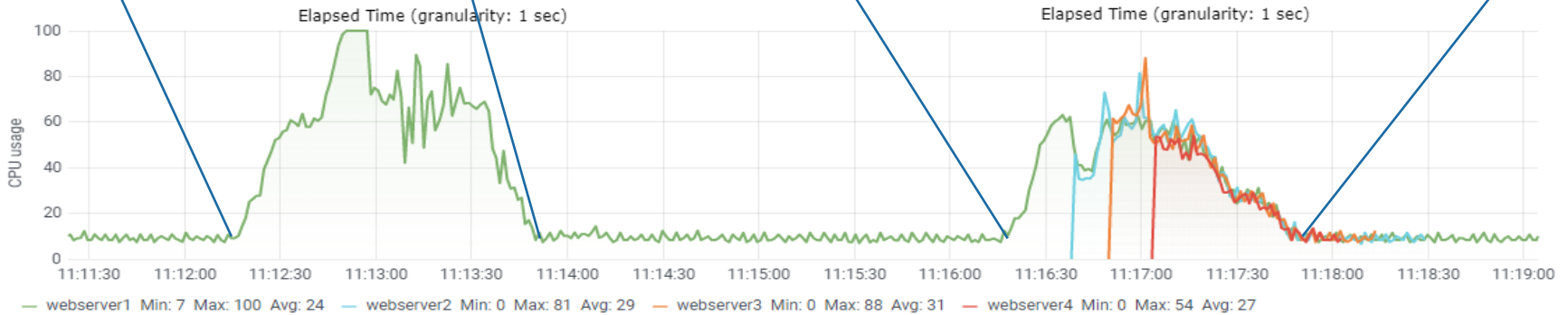
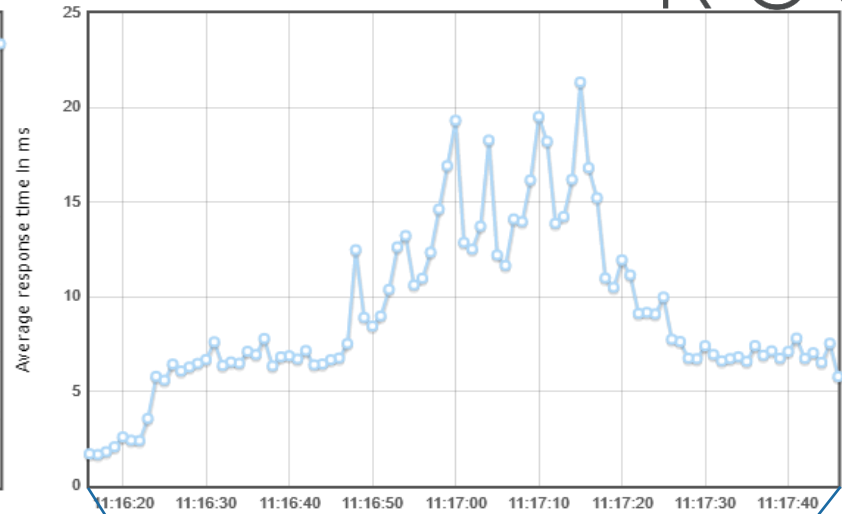
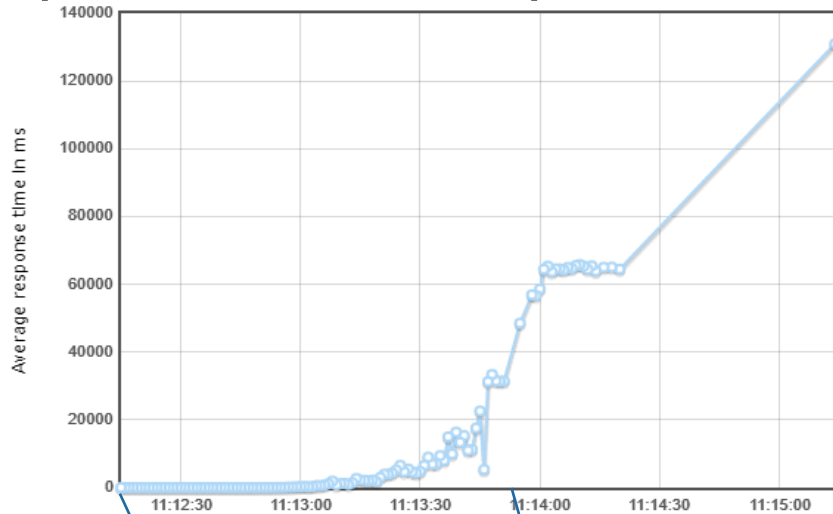




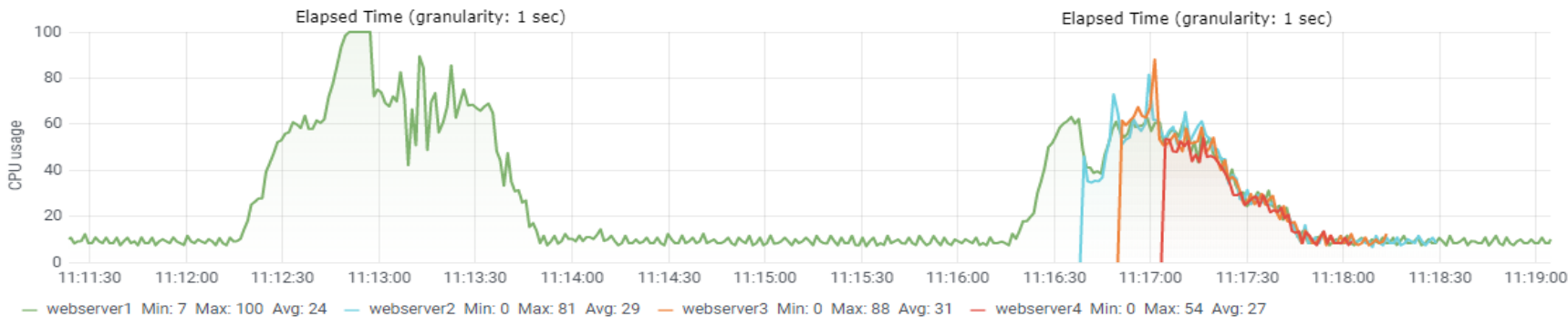
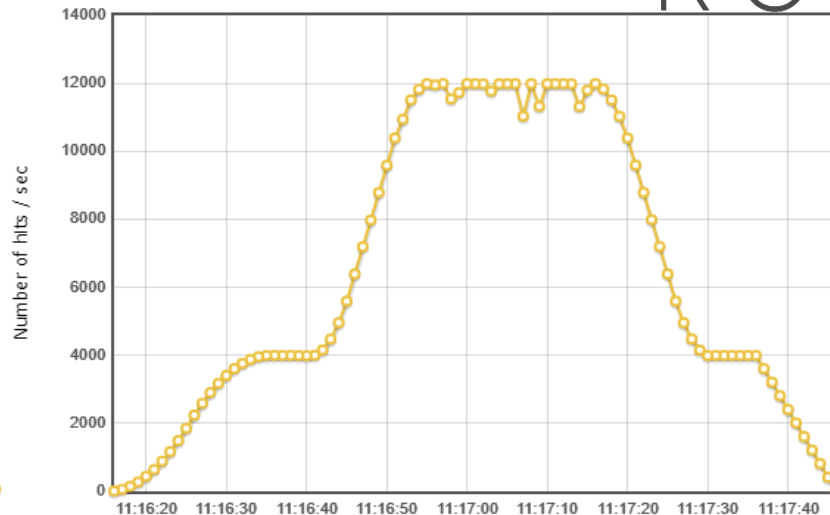
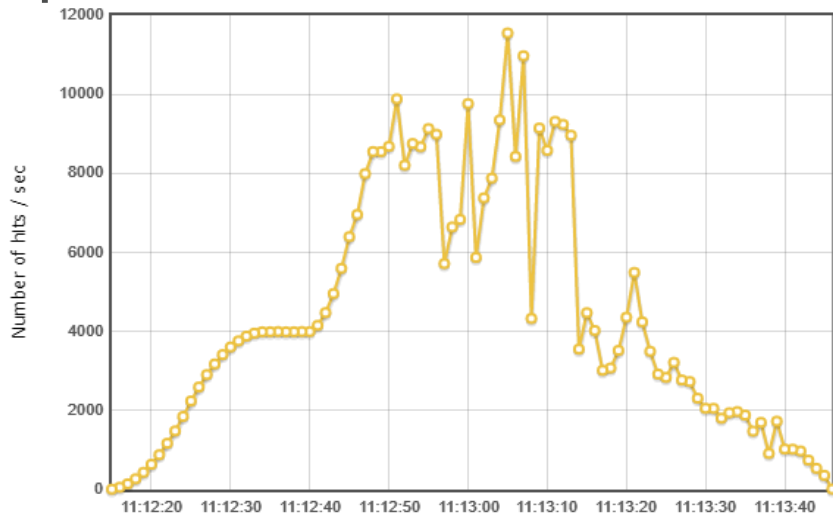
# Experiments: Response time



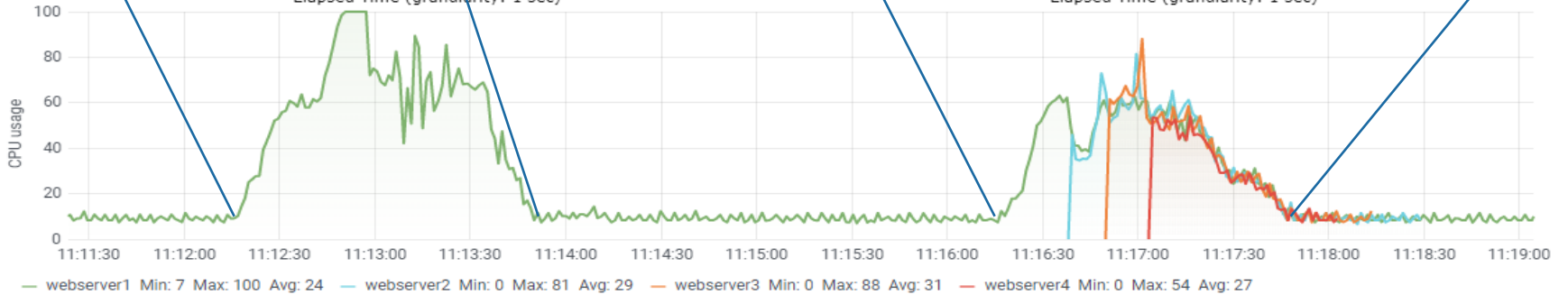
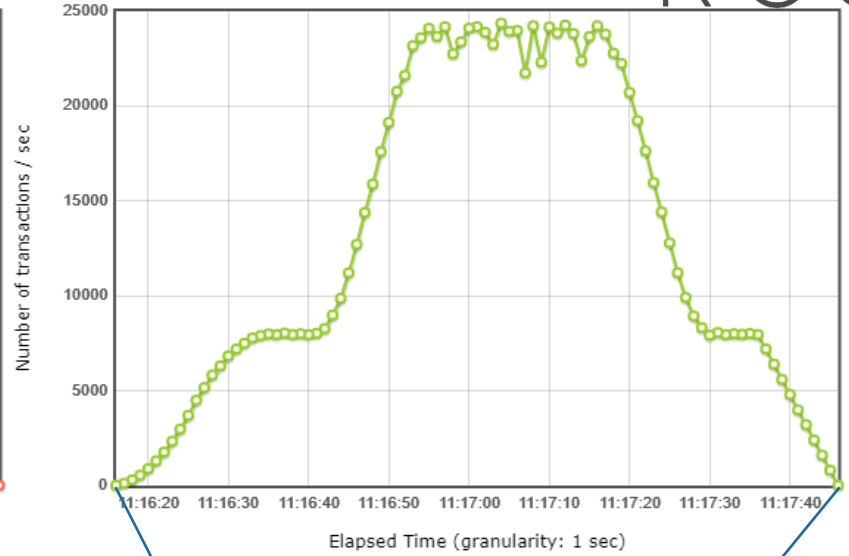
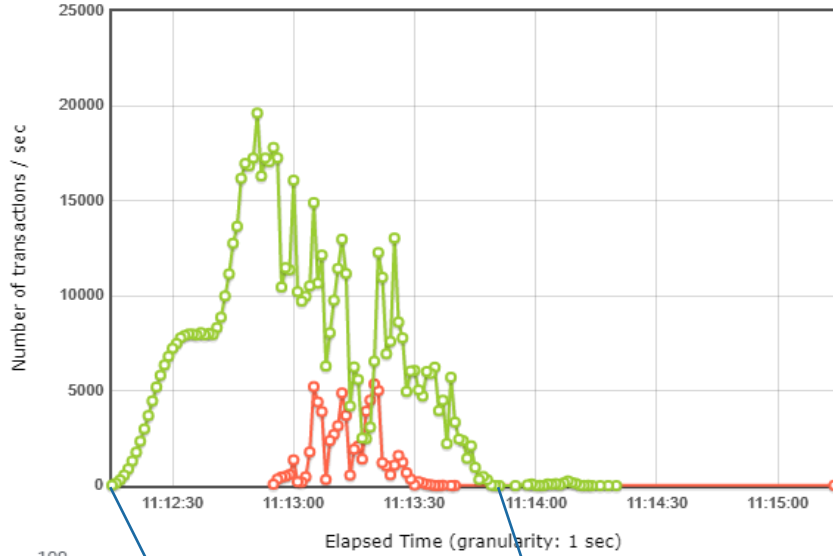
# Experiments: Response time



# Experiments: Number of hits



# Experiments: Number of transactions



# Benchmarking prototype conclusion

- SUCCESSFULLY HEADED OFF INTOLERABLE LOAD TO FURTHER SERVERS
- SNMP IS A VERY FITTING PROTOCOL WITH MINOR INCONVENIENCES
  - + Intuitive mapping of SNMP functions to control loop components
  - + Fits communication protocol requirements almost fully
  - + Large number of natively supported devices
  - Somewhat weak encryption and authentication (DES, AES256, MD5)
  - No easy way to incorporate roles
- CURRENTLY SUPPORTED PROTOCOLS (DISCUSSION VERY WELCOME!)
  - Plain UDP (to compare overhead, some data, no intensive testing yet)
  - Plain TCP (to compare overhead, no comparable data yet)
  - gRPC (protobuf implementation, no comparable data yet)
  - ZeroMQ (request response, no comparable data yet)
  - SNMPv3

# Research questions

1) HOW CAN WE DEFINE **UNIFORM COMMUNICATION INTERFACES AND PROTOCOLS** FOR DISTRIBUTED SELF-ADAPTIVE SYSTEMS THAT RELY ON THE MAPE CONTROL LOOP?

2) WHEN MULTIPLE **DISTRIBUTED MAPE LOOP COMPONENTS** OF THE SAME TYPE HAVE TO INTERACT WITH EACH OTHER TO CREATE A CONTROL DECISION, **HOW DO THEY SYNCHRONIZE?**

3)

# Synchronization of MAPE components with Roles



## 1. SYNCHRONIZATION FOR EVERY DECISION

- Almost fully domain specific and case dependent, little to no generalization possible

## 2. MASTER ELECTION FOR ONE DECIDING AUTHORITY (MASTER/SLAVE ROLES)

- Some generalization possible (specific leader methods)
  - Monitoring-master is able to issue database queries
  - Analysis-master is able to query slave components and issue communication to Planning-master
  - Planning-master is able to query slave components and issue communication to Execution-master
  - Execution-master is able to issue Execution in slave components
- Slaves are bound to master-slave communication (pull/push)
- **Martin Weißbach's protocol** could be used to issue (re)-election when valid configurations are known (in case of error or insufficient performance)

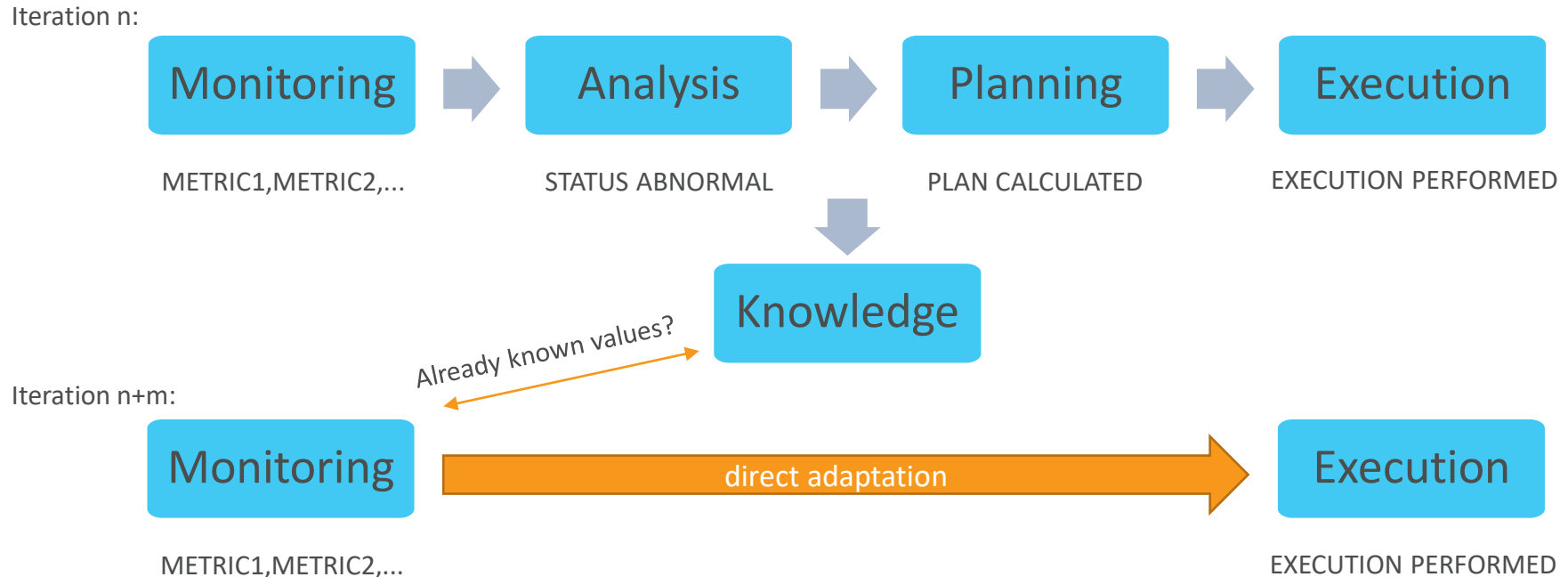
# Research questions

- 1) IS IT POSSIBLE TO DEFINE **UNIFORM COMMUNICATION INTERFACES AND PROTOCOLS** FOR DISTRIBUTED SELF-ADAPTIVE SYSTEMS THAT RELY ON THE MAPE-K CONTROL LOOP?
  
- 2) WHEN MULTIPLE **DISTRIBUTED MAPE-K LOOP COMPONENTS** OF THE SAME TYPE HAVE TO INTERACT WITH EACH OTHER TO CREATE A CONTROL DECISION, **HOW DO THEY SYNCHRONIZE?**
  
- 3) HOW CAN **MONITORING KNOWLEDGE** FROM EARLIER MAPE-K ITERATIONS BE USED TO **ENHANCE THE ADAPTATION PERFORMANCE?**



# Using monitoring knowledge to enhance adaptation performance

- IN THEORY, PERFORMING ITERATIONS THAT ARE NOT BOUND TO THE LOGICAL SEQUENCE OF THE MAPE-LOOP MAY ENHANCE PERFORMANCE



# Next milestones

## 1. VERY SOON

- a) Full-Paper: On Adopting SNMP as Protocol for the Communication in Distributed Control Loops for Self-adaptive Systems (dissertation contribution)

## 2. EARLY TO MID 2021

- a) Demo-paper: Benchmarking platform to compare communication protocols for control loops
- b) Short-/Full-paper: „Comparison of Communication Protocols/Platforms for Distributed Self-adaptive Systems on the Basis of Control Loops“ (dissertation contribution)

## 3. MID TO LATE 2021

- a) Contribution on using the role-concept to add synchronization to the benchmarking platform (dissertation contribution)

## 4. LATE 2021 TO EARLY 2022

- a) Contribution on using monitoring knowledge to enhance the adaptation performance of the MAPE control loop (dissertation contribution)

## 5. LATE 2022

- a) Submission and defence of the dissertation manuscript