Karlsruhe Institute of Technology

A scalable architecture for online anomaly detection of WLCG batch jobs

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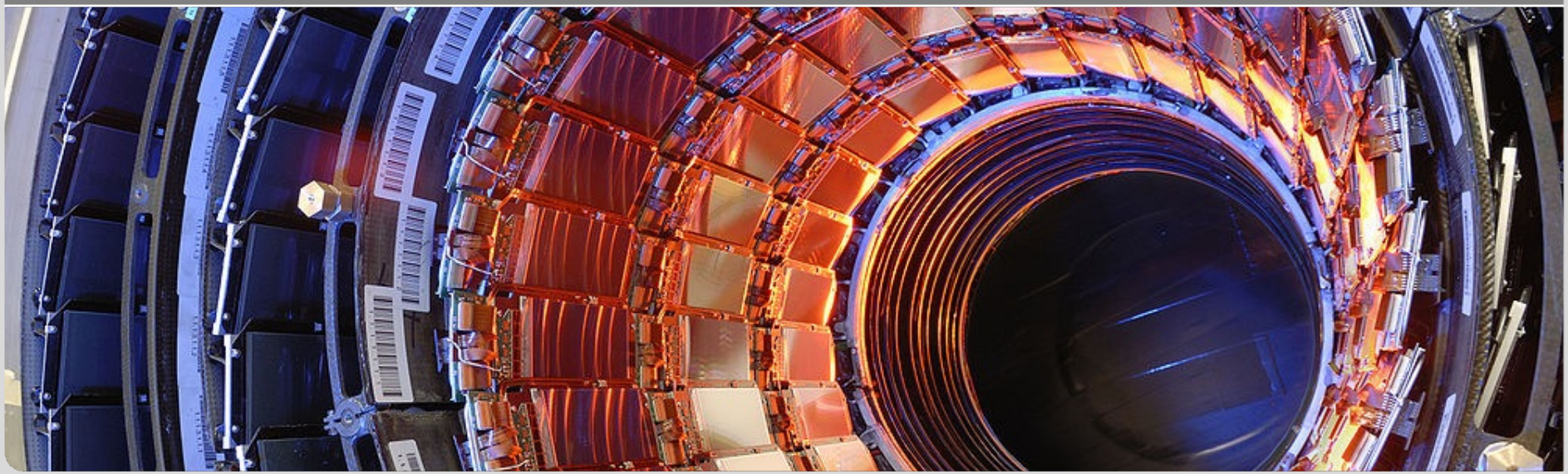


Payload Monitoring Tool

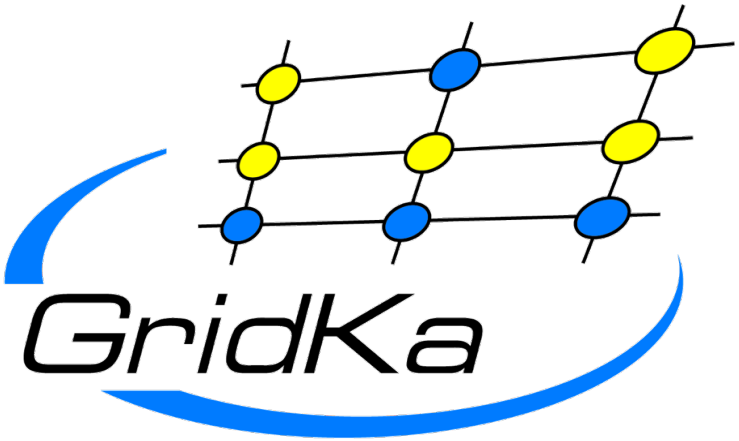
- Process and network traffic monitoring tool
  - Monitoring process trees of batch system jobs
  - Network monitoring based on libpcap
  - Logging of network traffic on packet level
  - Association of process and network data
- Internal preprocessing
  - Categorisation into internal and external network traffic
  - Grouping of traffic by connection

- Stable operation for several months
- Already proven to be useful
  - For example: Detected a class of misbehaving jobs producing loads of external traffic because of a software bug
    - Firewall was heavily loaded and GridKa not reachable
    - Due to fine-grained monitoring, fast identification and reaction on issue

Operation on GridKa Cluster

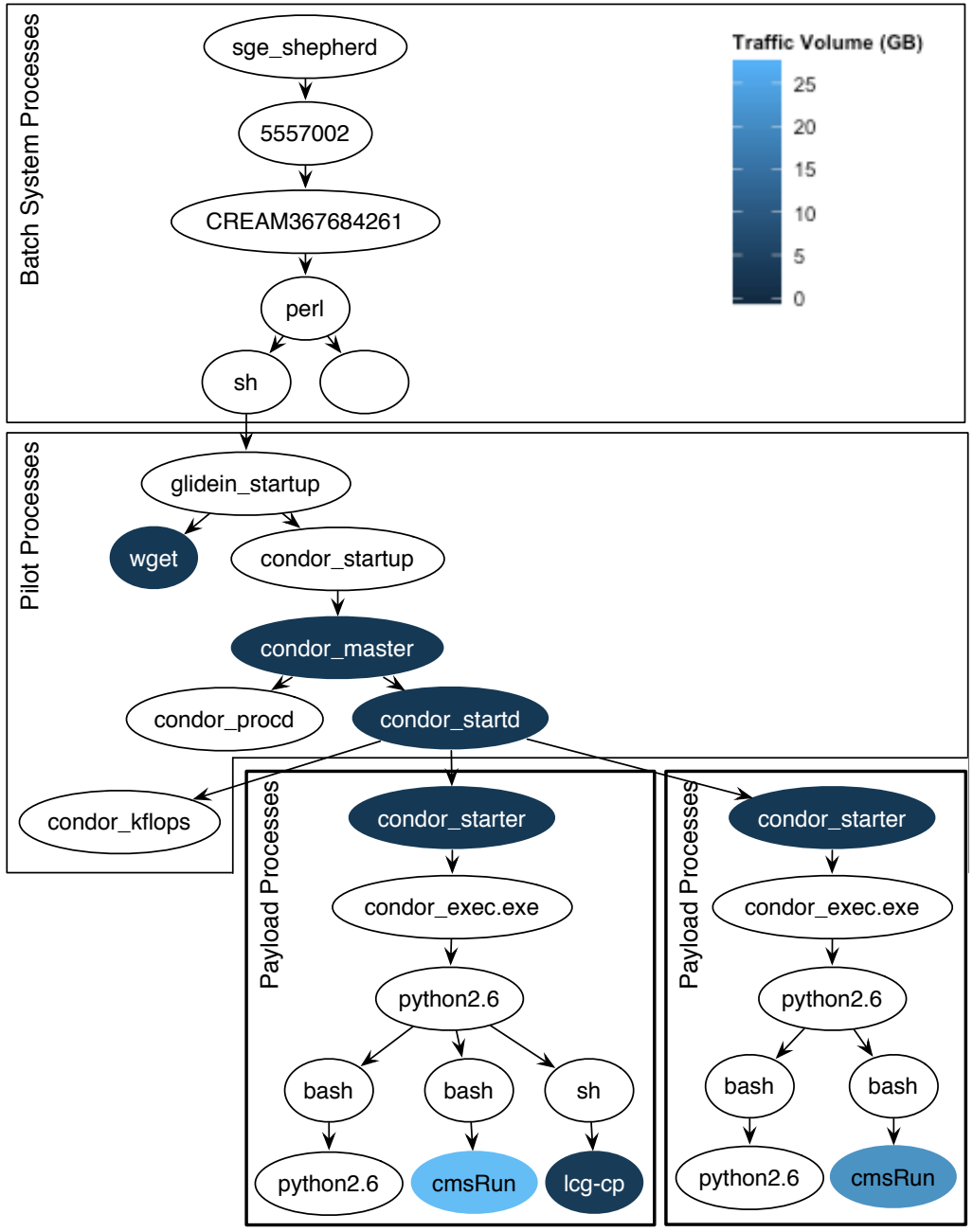
- Tier 1 computing centre
  - Supports all four major CERN LHC collaborations as well as AUGER, BELLE2, COMPASS, and others
  - Operation of ~600 worker nodes
  - Provision of ~13,000 job slots
  - Batch system: Univa Grid Engine

- Prototyp monitoring on 2 racks
  - 2x16 worker nodes, ~800 job slots
  - Stable operation since July ‘14



Example Pilot

- Up to 4 million nodes
- Up to 100 payloads
- Avg. duration 12 h
- Depth: 17
- Process <10 s cut



Issues

- Memory demands
  - Anomaly detection based on trees
  - Anomaly detection based on traffic time-series
- Algorithmic complexity
- Learning of prototypes

Unique encoding of edges

	Data Type	Size (B)
pid	`int`	4
ppid	`int`	4
gpid	`int`	4
uid	`int`	4
tme	`real`	4
exit_tme	`real`	4
exit_code	`int`	4
name	`string`	l_1
cmdline	`string`	l_2
		$28 + l_1 + l_2$

Memory requirements of single node (B)

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Tree with 4 million nodes requires around 160 MB for values

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Additional memory for prototypes

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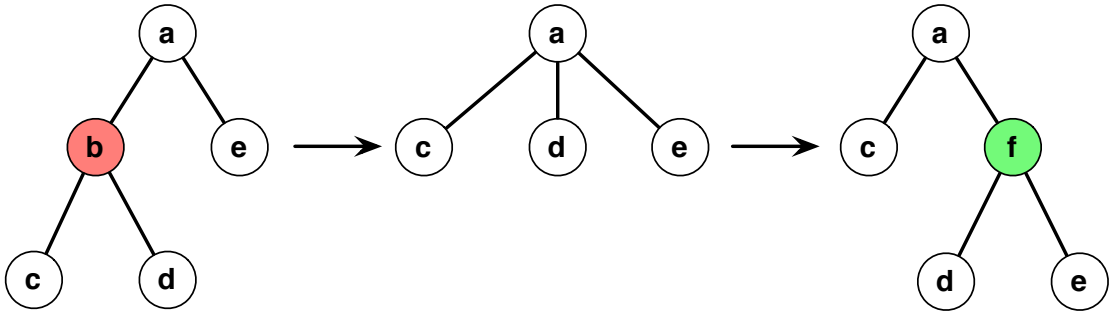
cmdline	`string`	l_2
		$28 + l_1 + l_2$

Memory requirements of single node (B)

Issues

- Memory demands
- Algorithmic complexity
  - Similarity of trees
  - Handling of noise (e.g. repetition of processes, different software versions)
  - Correlation with network saturation (e.g. runtime of processes)
- Learning of prototypes



Example: Tree edit distance (e.g. $O(n^3)$ time and $O(mn)$ space complexity*)

* M.Pawlik and N.Augsten. RTED: A Robust Algorithm for the Tree Edit Distance. PVLDB. 2011.

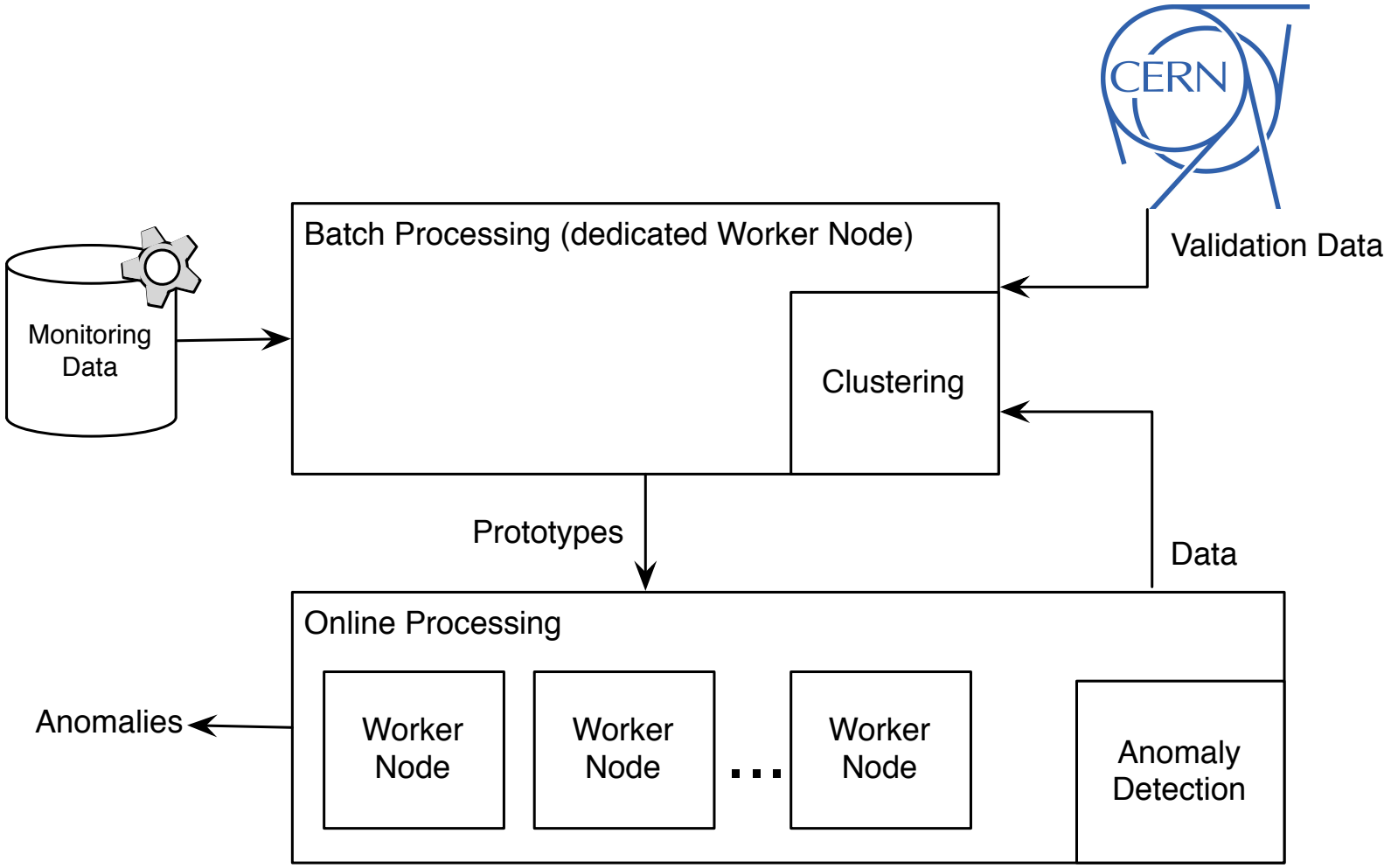
Issues

- Memory demands
- Algorithmic complexity
- Learning of prototypes
  - Centralised vs distributed learning
  - Evolution of batch jobs

Requirements Online Anomaly Detection

- Uninterrupted operation of batch system
  - Low communication overhead
  - Low memory consumption and CPU load on worker nodes
- Fast and accurate near real-time anomaly detection
  - Focus on reduction of false positive notifications
- Robust approach
- Unsupervised approach
- Scalability

Overview Online Anomaly Detection

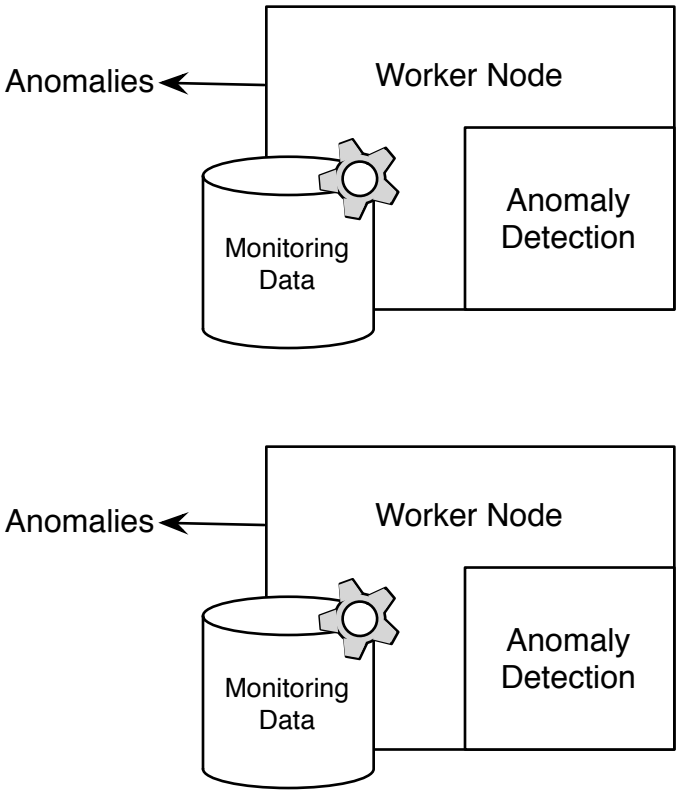


Local Anomaly Detection

- Each worker node does the whole detection workflow

- Advantages
  - No communication overhead

- Disadvantages
  - High CPU load on worker nodes
  - Context is ignored
  - Prototype learning
    - Different models on each node
    - Central node for model calculation

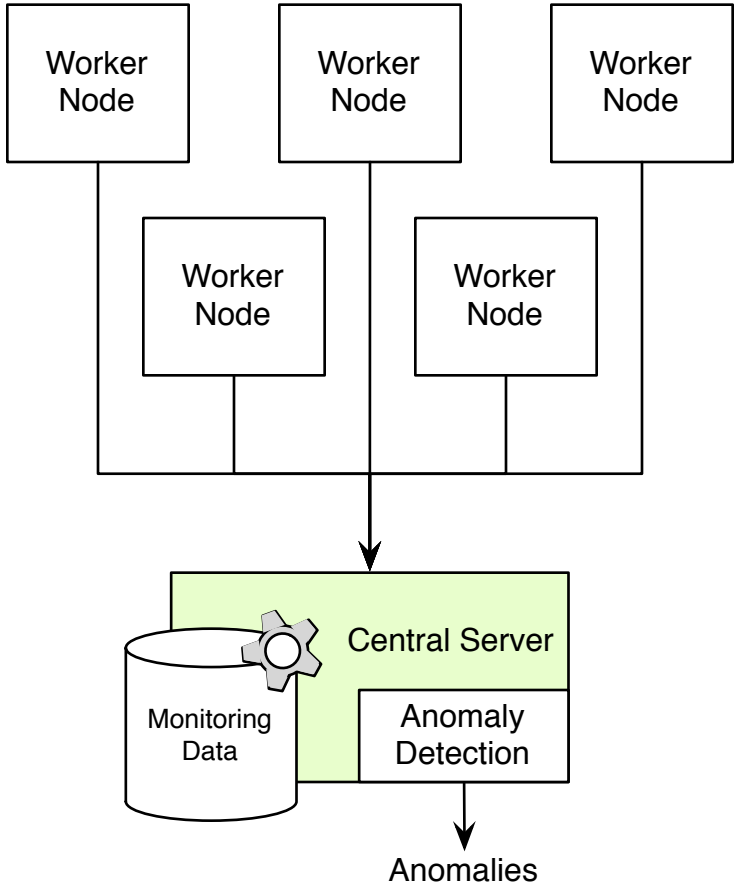


Centralised Systems

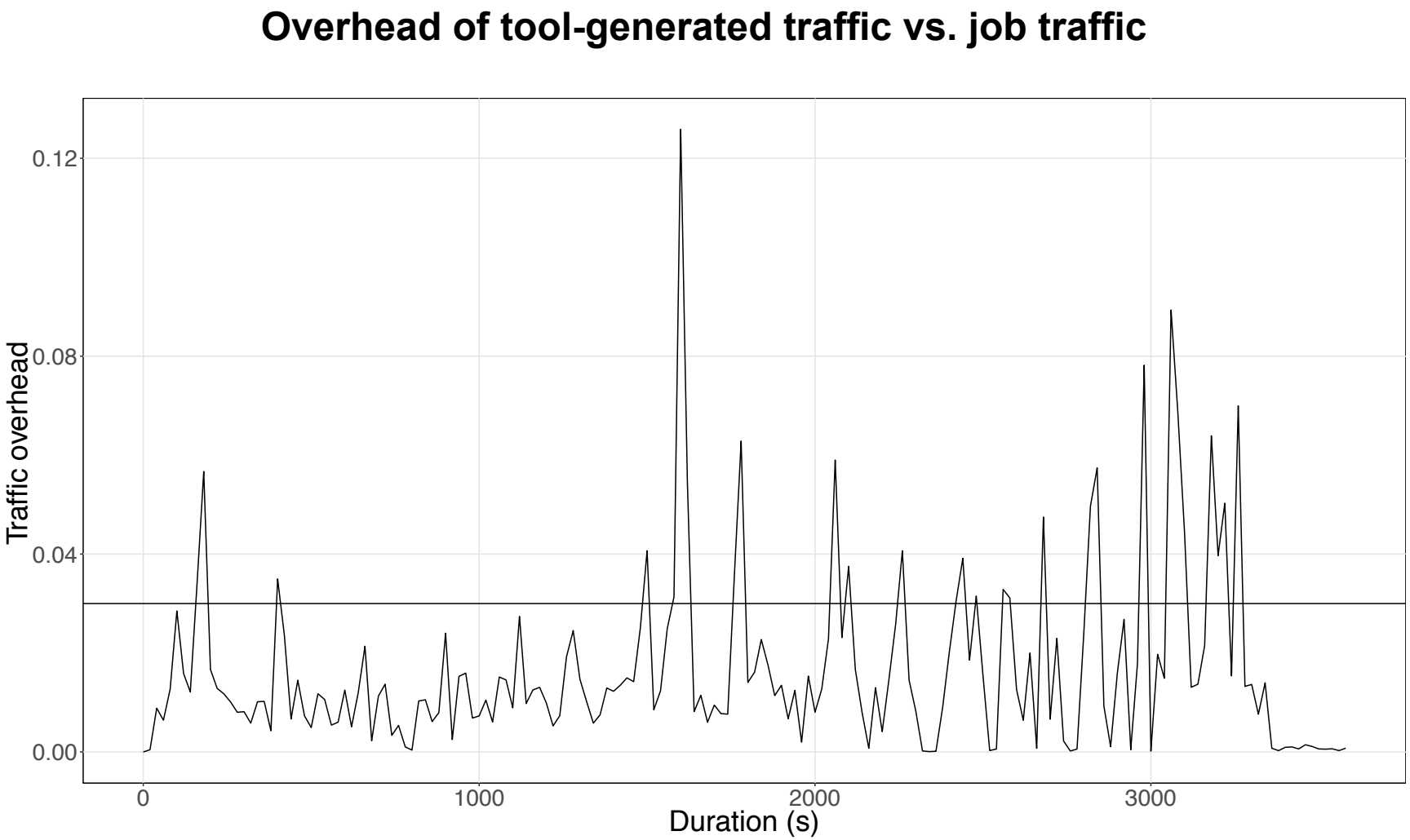
- Anomaly detection centralised on single server
- Worker nodes send monitoring information

- Advantages
  - Easy to manage
  - Data consistency and coherence
  - Centralised prototype model

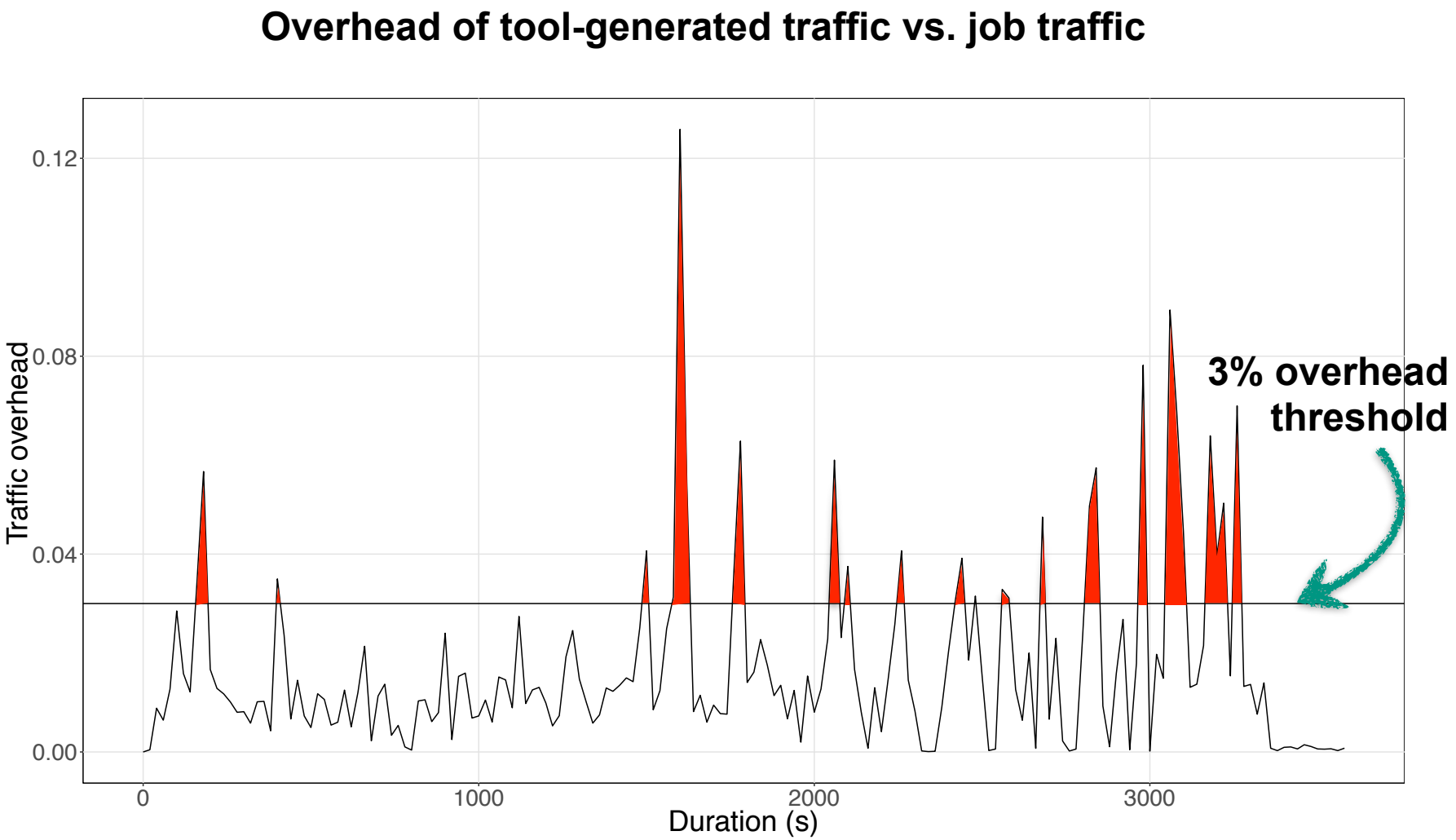
- Disadvantages
  - High CPU load on server
  - High memory demands on server
  - Communication overhead
  - Single point of failure
  - Server is bottleneck to scalability and performance



Centralised Systems

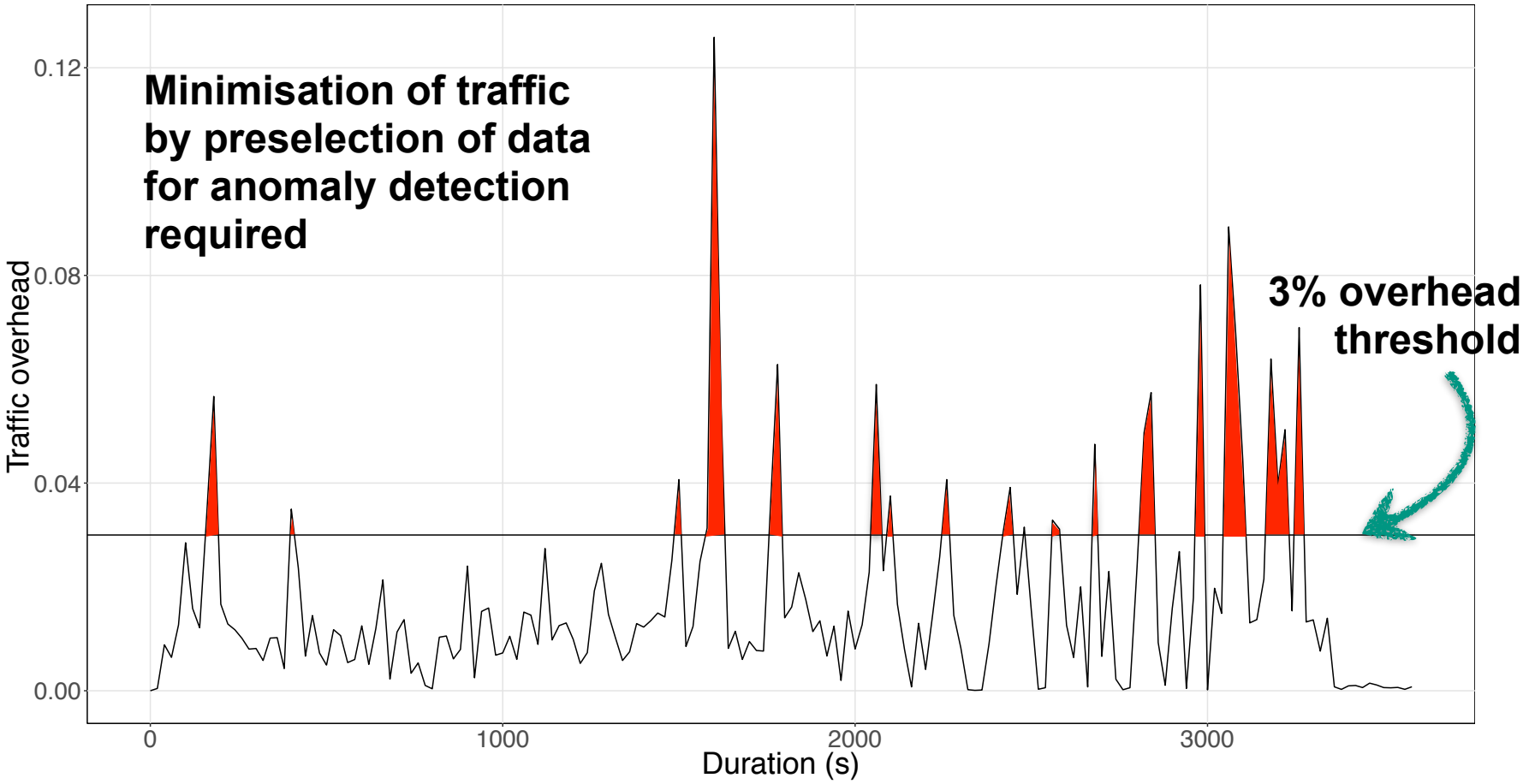


Centralised Systems



Centralised Systems

Overhead of tool-generated traffic vs. job traffic

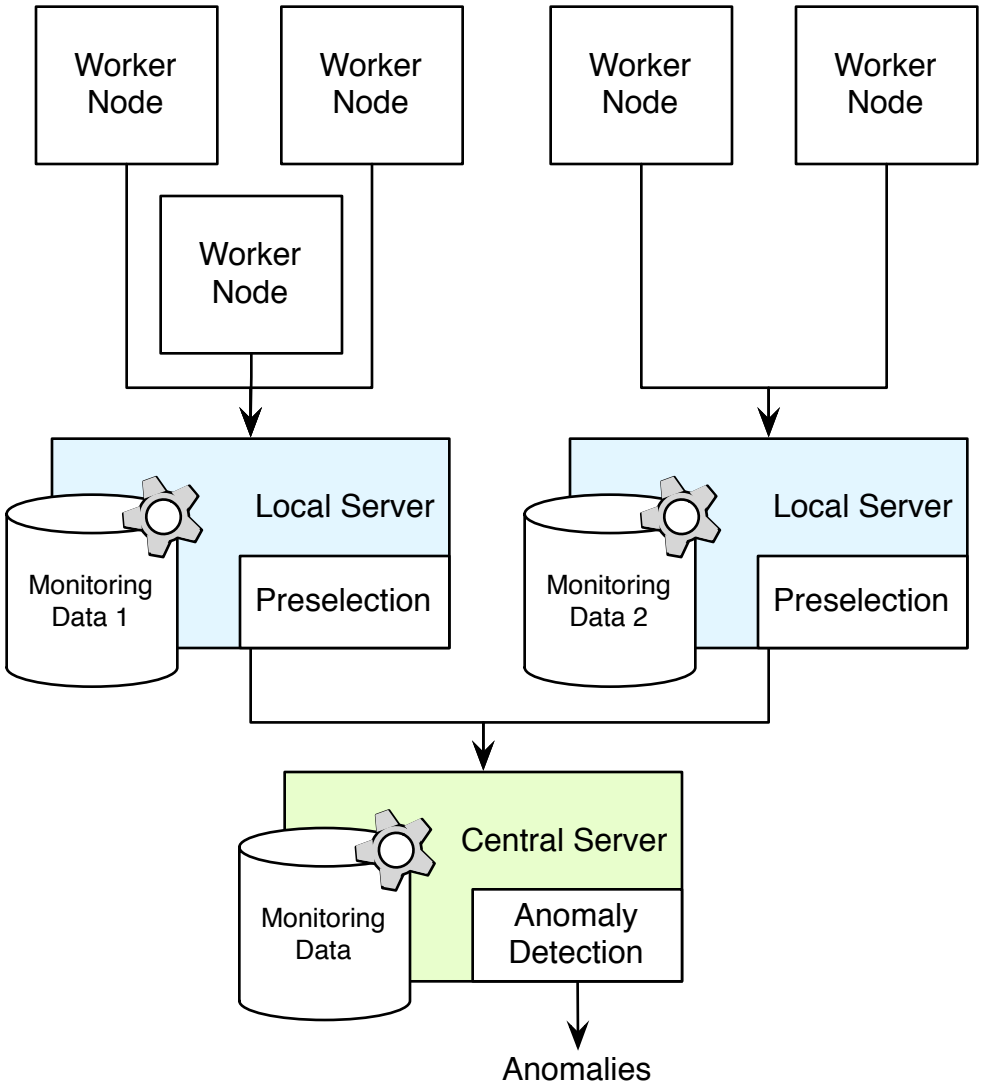


Hierarchical Systems

- Allocation of a group of worker nodes to several servers
- Logical hierarchy of processing

- Advantages
  - Scalability
  - Data consistency and coherence
  - Centralised prototype model

- Disadvantages
  - Hardware requirements for servers
  - Communication overhead
  - Single groups may fail

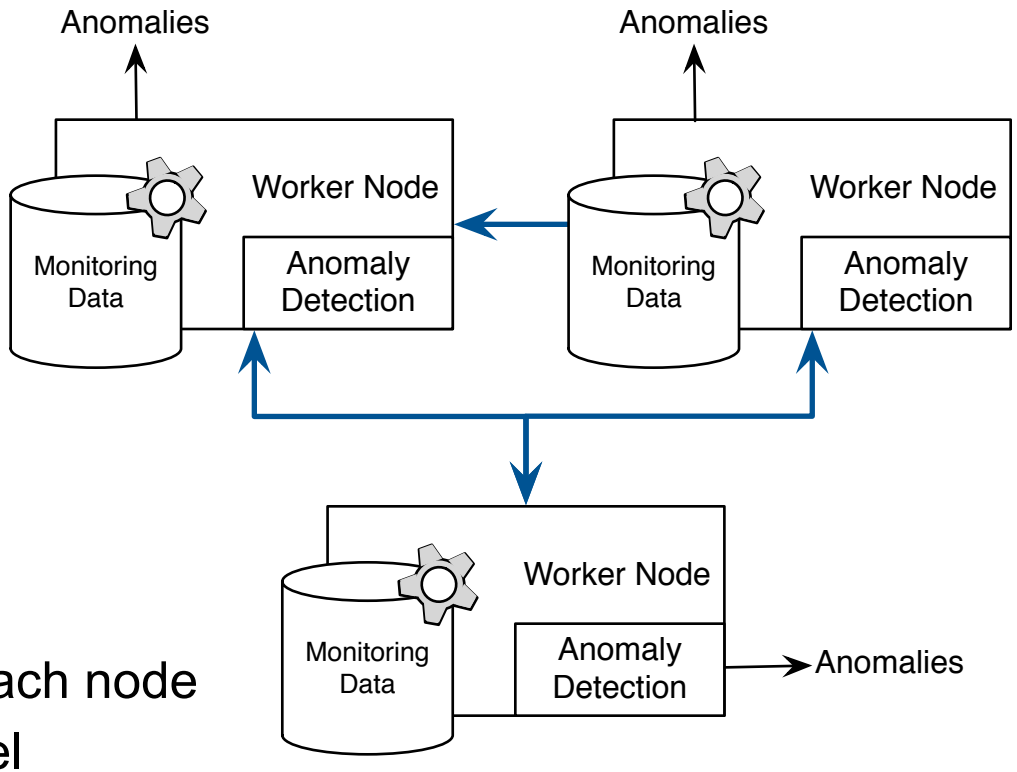


Peer-to-Peer Systems

- Any node can exchange data with any other node

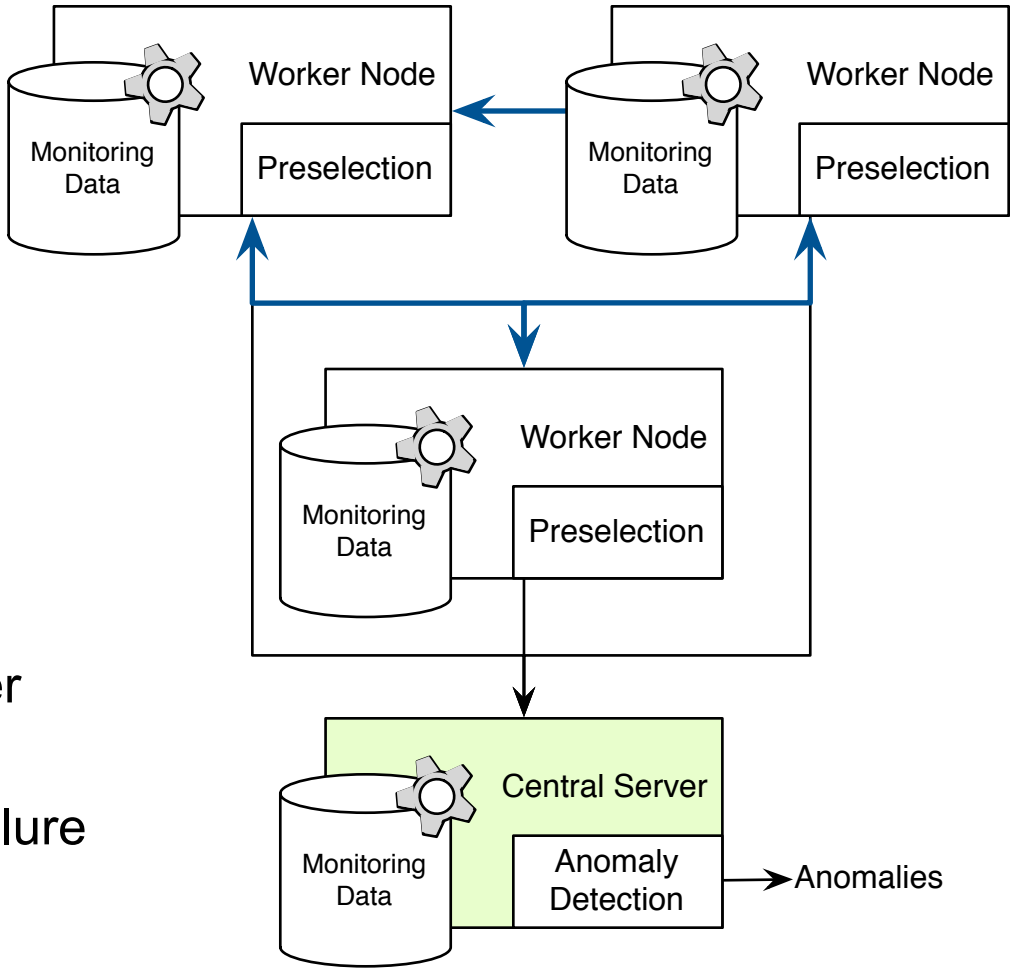
- Advantages
  - Fault tolerance to failure/shutdown
  - Horizontal scalability

- Disadvantages
  - Manageability
  - Network flooding
  - High CPU load
  - Prototype learning
    - Different models on each node
    - Central node for model calculation



Hybrid Peer-to-Peer Systems

- Additional central server to gather required information
- Advantages
  - Data consistency and coherence
  - Centralised prototype model
- Disadvantages
  - CPU load on server
  - Memory demands on server
  - Communication overhead
  - Server as single point of failure and bottleneck

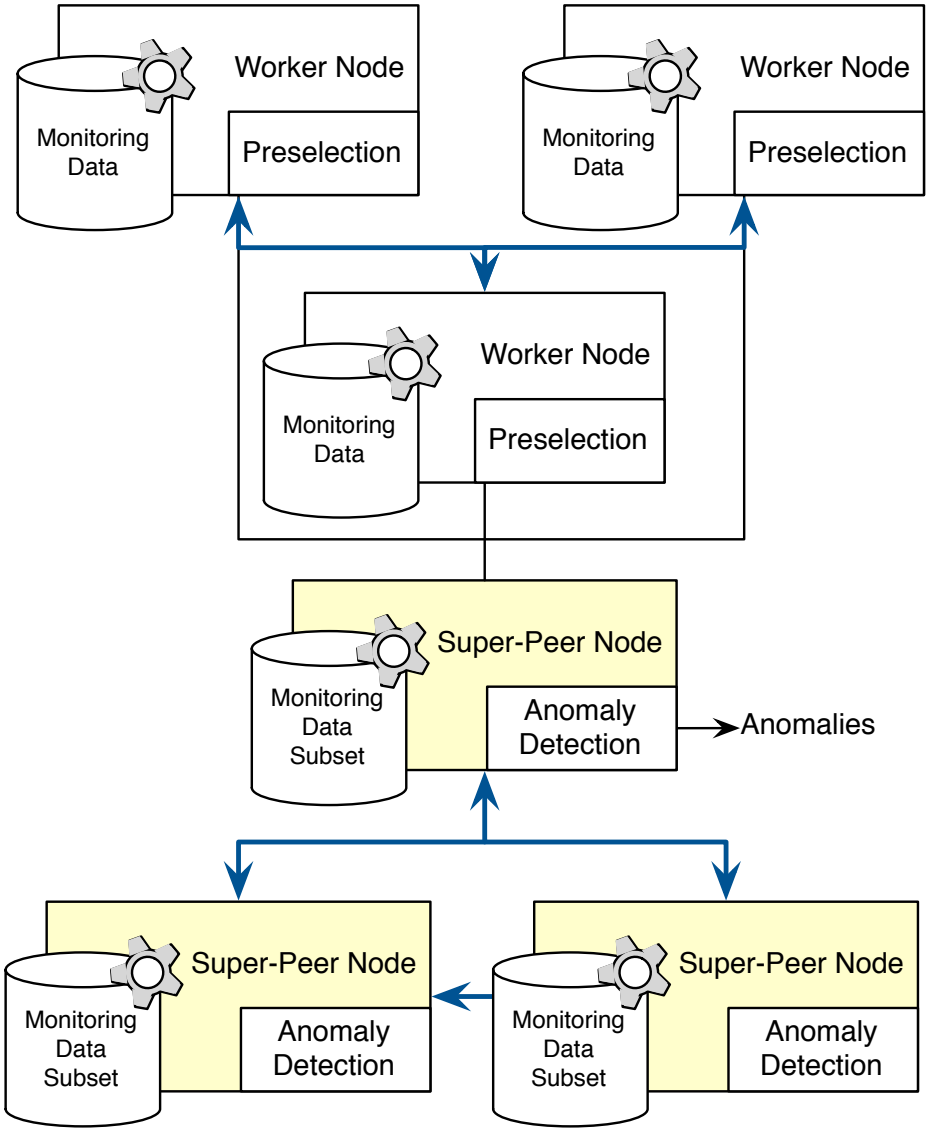


Super-Peer Systems

- Super-peers act as centralised servers to a subset of worker nodes
- Super-peers are connected to each other as peers
- Dynamic assignment of responsibilities

- Advantages
  - Flexible resource utilisation
  - Autonomous units

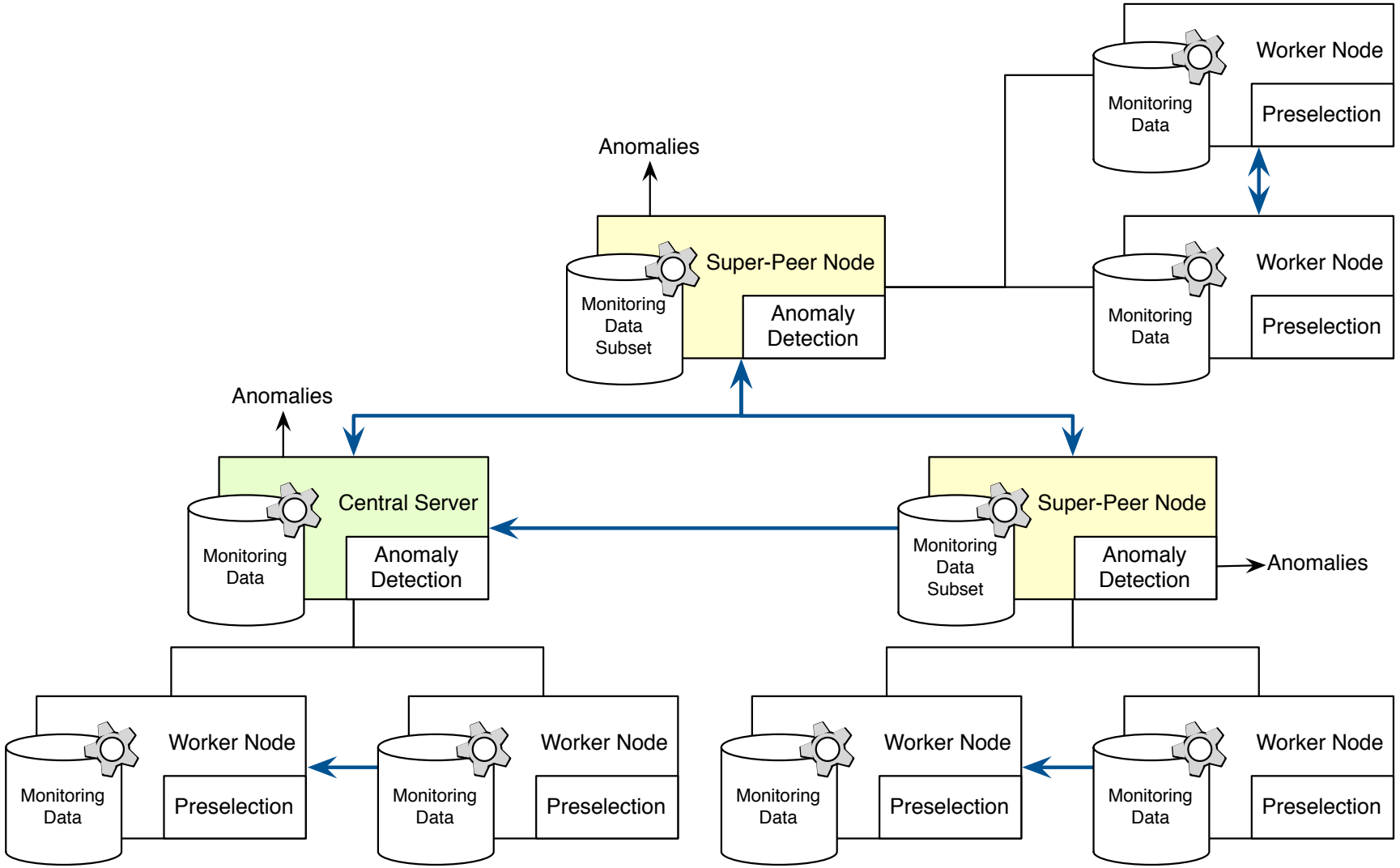
- Disadvantages
  - Prototype learning
  - Communication overhead



Concept of Scalable Architecture

- High computational cost for distance measurement but also memory demands require distributed approach
- High flexibility and heterogeneity of batch system require fault tolerant autonomous units/cluster
- Monitoring allows detection of unsaturated worker nodes
- To reduce communication overhead algorithm has modular design

Concept of Scalable Architecture



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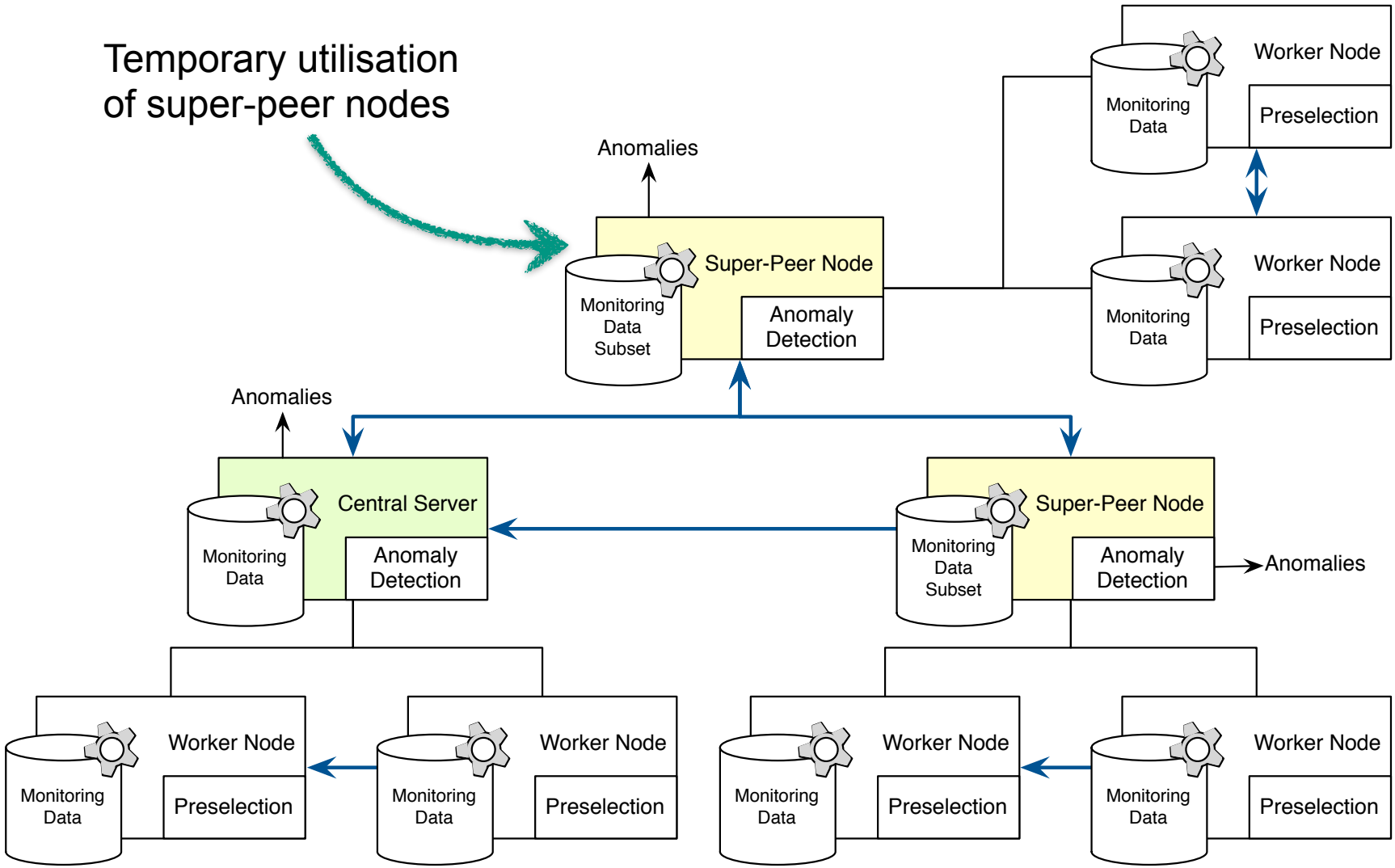
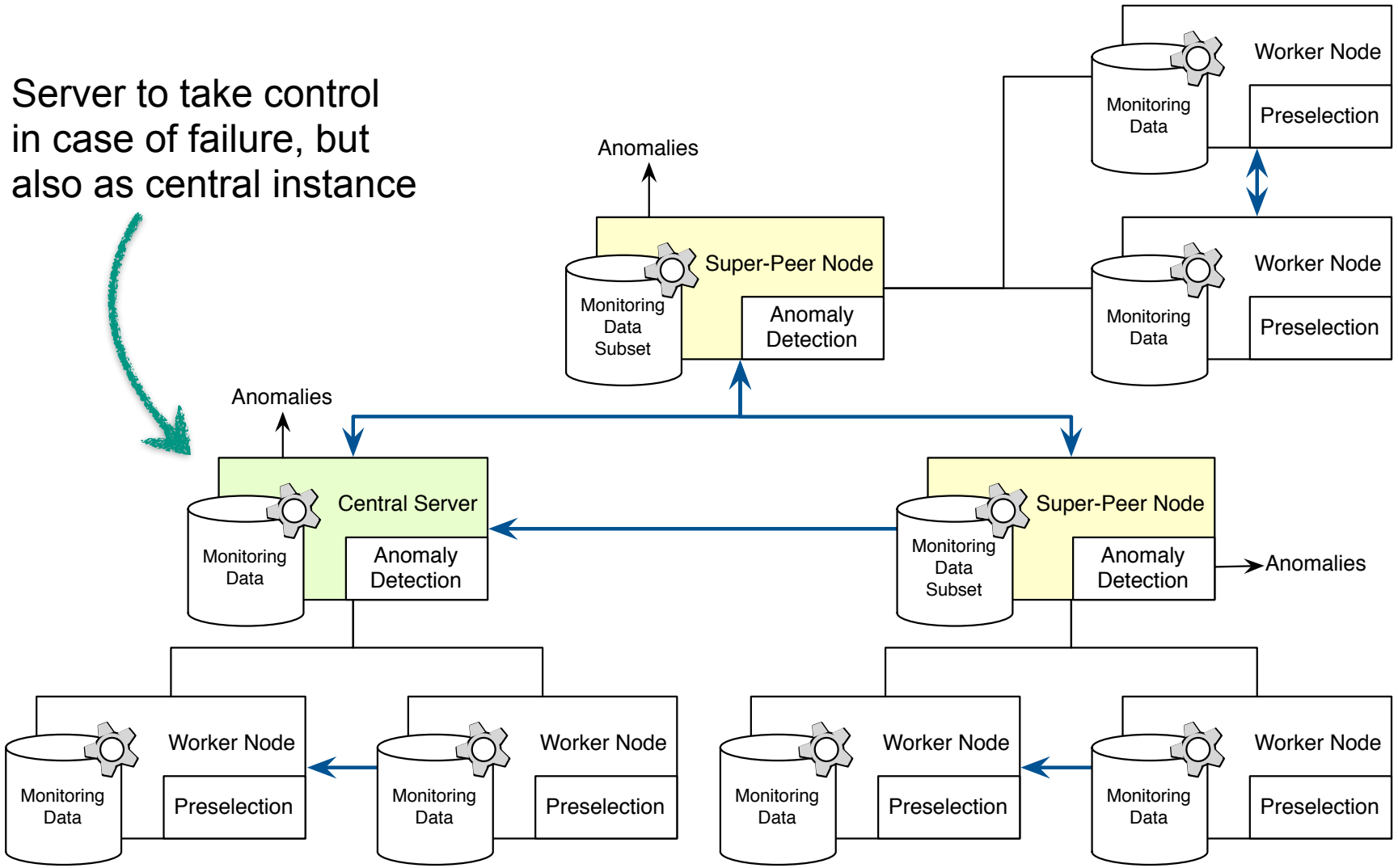


Concept of Scalable Architecture

Server to take control
in case of failure, but
also as central instance



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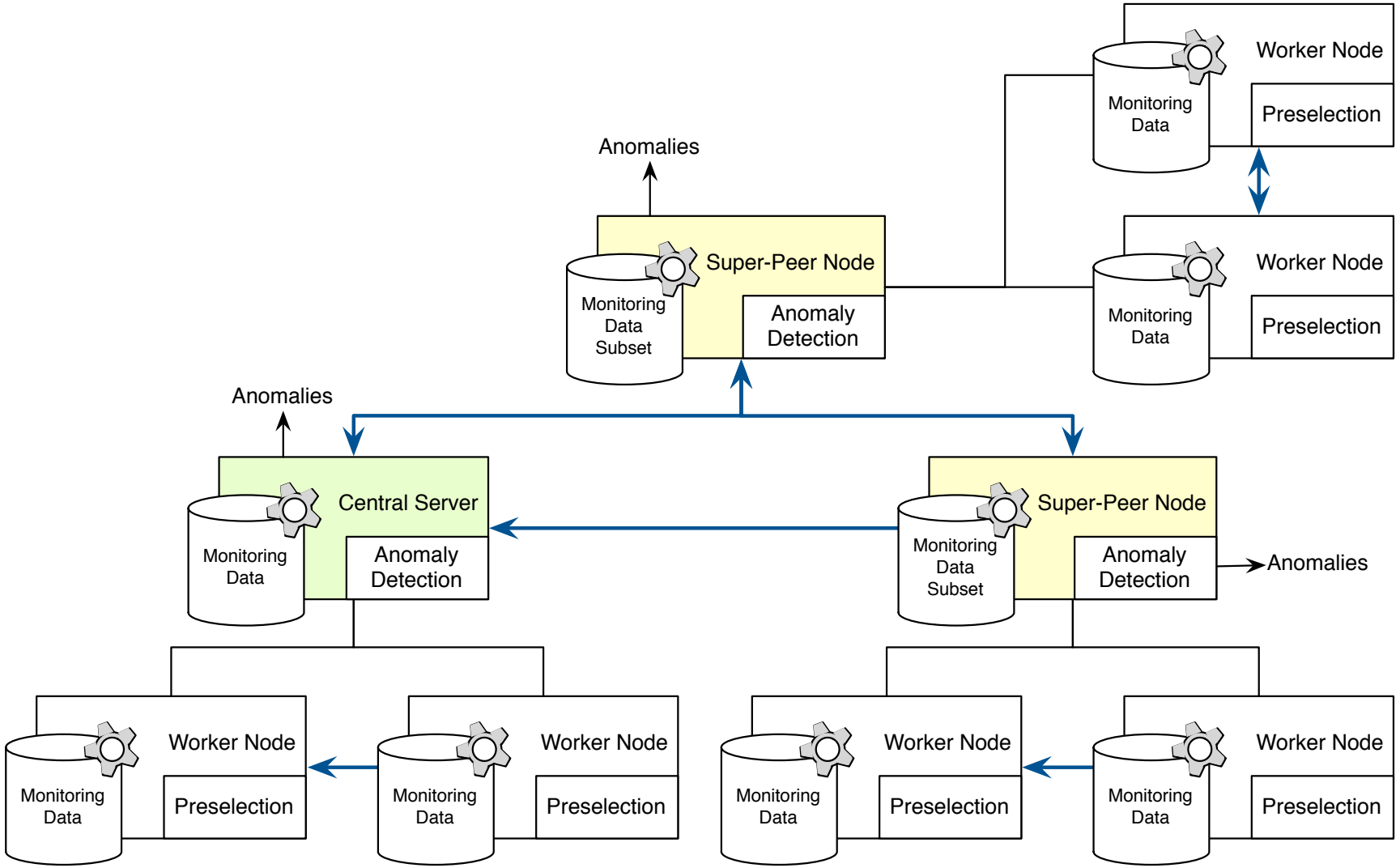

Summary and Outlook

- Scalable and modular architecture for anomaly detection of WLCG batch jobs
  - Based on batch job-level monitoring on single worker nodes
  - Different contexts (e.g. same/different rack, or computing centre)
- Opportunistic resource usage
  - Unsaturated worker nodes used as super-peers
  - Additional server as a failover super-peer node

- Further improvements
  - Reduction of communication overhead
    - Compression of data formats
    - Improved preselection
  - Reduction of CPU load
    - Incremental distance measurement
  - Reduction of memory demands

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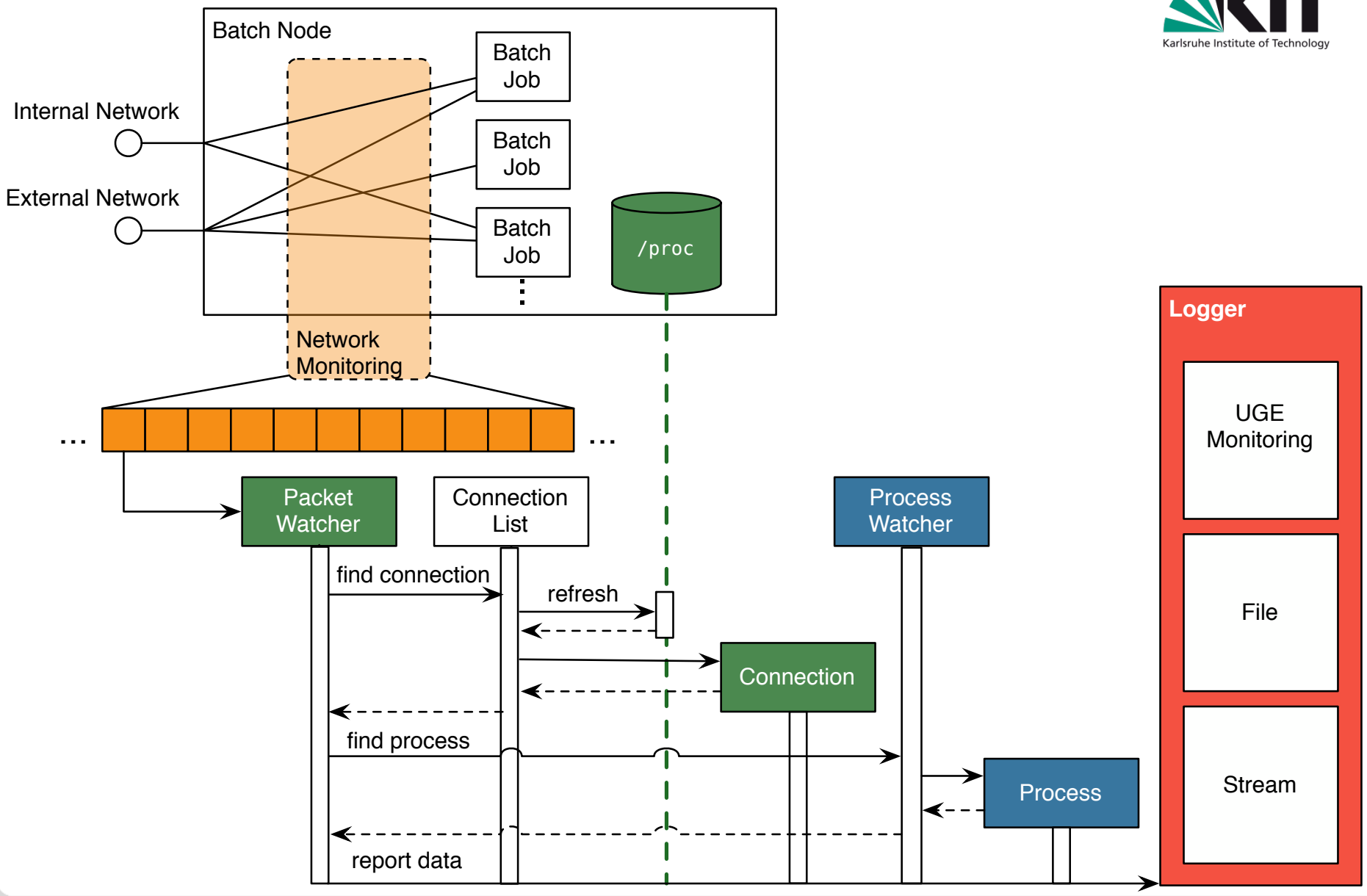
Questions?


Batch Node
Batch Job
Batch Job
Batch Job
Internal Network
External Network
/proc
Network Monitoring
Logger
UGE Monitoring
File
Stream
Packet Watcher
Connection List
Process Watcher
find connection
refresh
Connection
find process
Process
report data