Supervising Quality Environments with an Autonomic Ledger (SQuEAL)

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IARIA ICAS 2026

AIAC-2026: AI and Autonomic Computing in 2026 special session

Joel Bennett

- MSc A.I. Graduate from Ulster University
- Autonomic Computing interest from MSc AI module: COM760 Autonomic Computing and Robotics

- IT Support Analyst, Terumo Blood & Cell Technologies, Larne, Northern Ireland. Providing holistic technology support experience in a GxP manufacturing environment for 17+ years.

- Patent pending on this research.

Agenda

- Problem Background
- Proposal
- Literature
- Concept

- Project
  - Design
  - Environment Simulation
  - Testing
  - Outputs

- Conclusions

Problem Background

Good Manufacturing Practice (GxP) environments

(e.g. pharmaceutical, food)

Quality Management System (QMS)

QMS

- Documentation controls around processes
- High cost and human effort

- Automated and computerized systems with electronic records raise complexity, effort and costs
- Industry 4.0

Proposal

Autonomic Computing

Proposes achievement of self-managing computerized systems to address rising complexity.

- Environmental and self-awareness
- Control Loop – MAPE-K
  (sensor inputs, effector outputs)
- Stateful Self management
  - self-CHOP
- Blockchain – immutable trusted record
  - self-healing and protecting

Literature

Related Research	
Manuel Sanchez, et. al 2020	**Autonomic computing in manufacturing process coordination in industry 4.0 context**
	Proposes a framework of processes made up of autonomic cycles enabling manufacturing systems to operate autonomously and self-managed, centred upon the idea of “Smart Products” configuration.
J. J. Mulcahy, et. al 2014	**Autonomic Software Systems: Developing for Self-Managing Legacy Systems**
	Adaptation of a legacy system with modern web services and self-recovery using an autonomic approach.
Ali, S. Shin, et. al 2022	**Blockchain-Enabled Open Quality System for Smart Manufacturing: Applications and Challenges**
	Recognises the incompatibility of QMS with Industry 4.0 and the potential role for blockchain in a trusted systems future state.

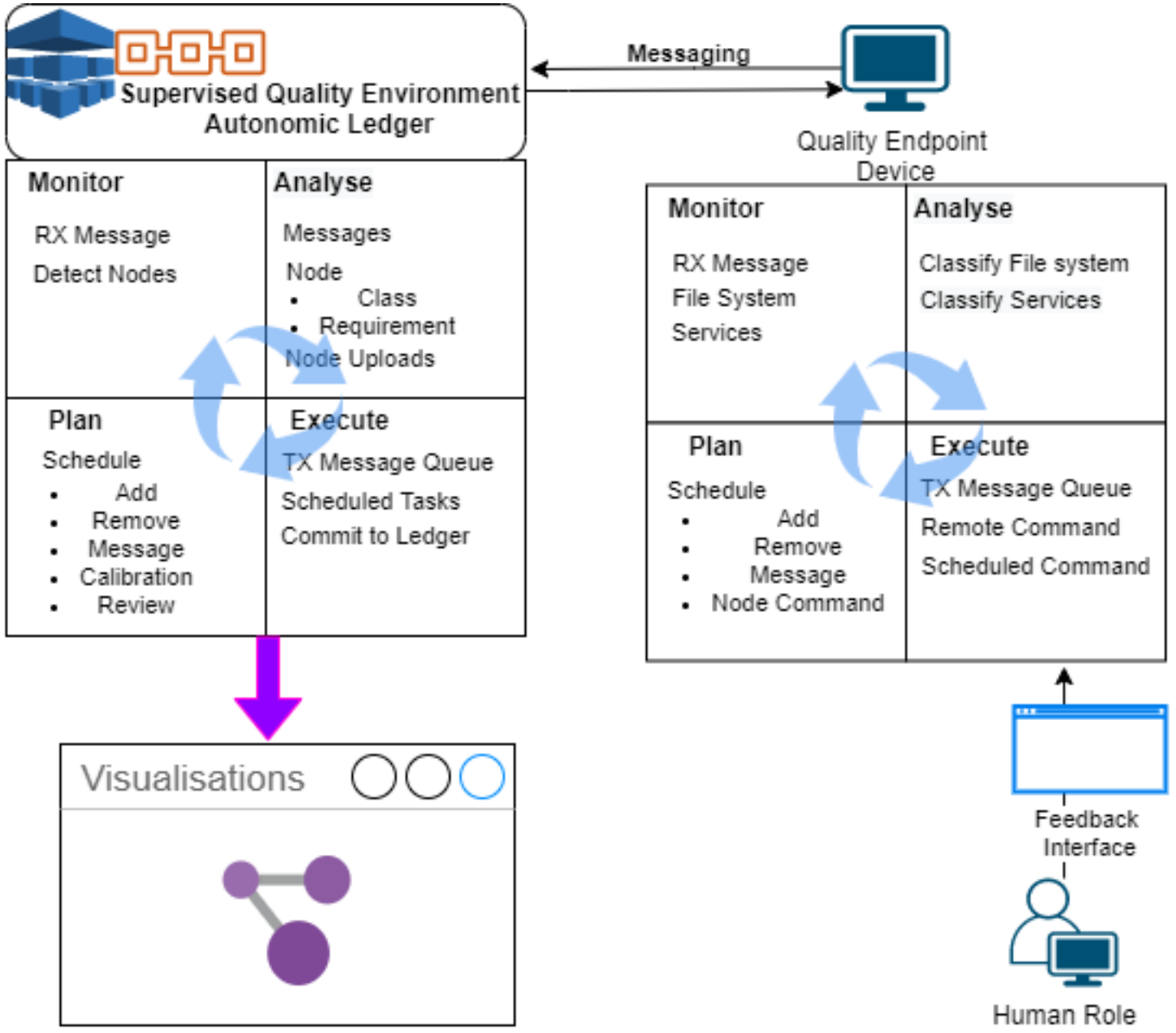
Manuel Sanchez, Ernesto Exposito, Jose Aguilar, “Autonomic computing in manufacturing process coordination in industry 4.0 context”, Journal of Industrial Information Integration, Volume 19, 2020

J. J. Mulcahy and S. Huang, "Autonomic Software Systems: Developing for Self-Managing Legacy Systems," 2014 IEEE International Conference on Software Maintenance and Evolution, Victoria, BC, Canada, pp. 549-552, doi: 10.1109/ICSME.2014.92., 2014

Ali, S.; Shin, W.S.; Song, H. “Blockchain-Enabled Open Quality System for Smart Manufacturing: Applications and Challenges”. Sustainability 2022, 14, 11677. https://doi.org/10.3390/su141811677, 2022

Proof of Concept

SQuEAL



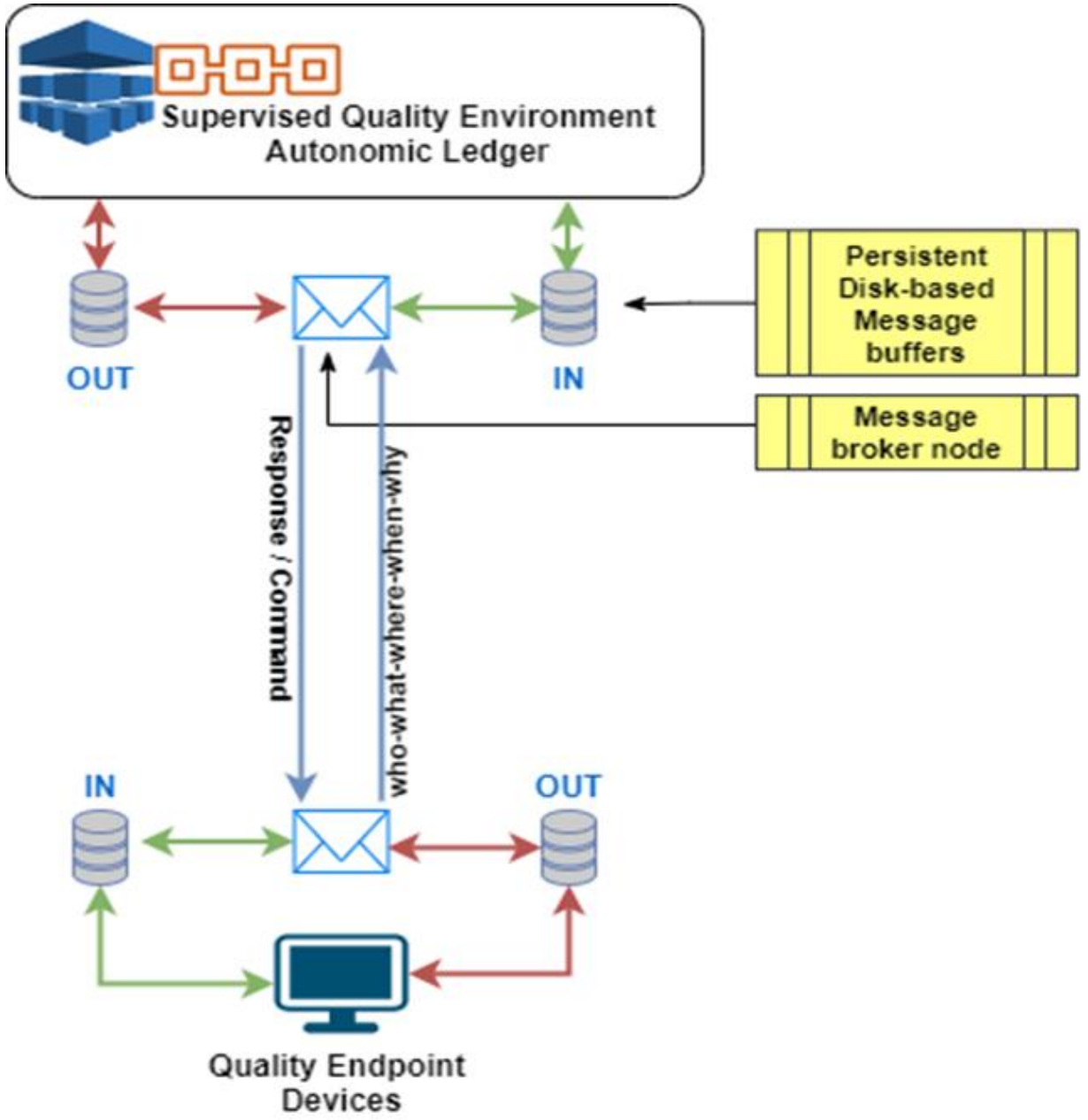
Project

Design

- DDD approach – question the domain
  - QMS = Features
  - AC = Approach
- **Scope:** Stateful QMS with trusted ledger
  - Document phases – **DQ,IQ,OQ,PQ,SOP,NC**
- AC principles
  - Loop – Monitor, Analyse, Plan, Execute, Knowledge
  - Persistence and Recovery – Blockchain, Messaging, States
- Construct AEP – OS interface functions
- Construct AL – Response Policies
- Construct Environment Simulation based on AEP
- Testing and Evaluation

Project

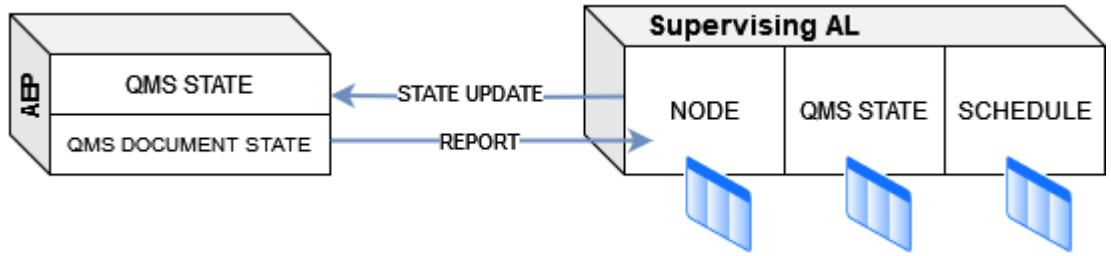
Design



Project

QMS Simulation

- Challenges
  - Live/Production QMS environment availability and integrity
  - Scaling of environment and activities
- Simulating relevant QMS activities
  - Scaling of environment, event type, quantity and actors
  - Reproducability and Repetition facilitates testing
- QMS Environment – Virtual Machine
  - Agents
  - Endpoints
  - Activities



Project

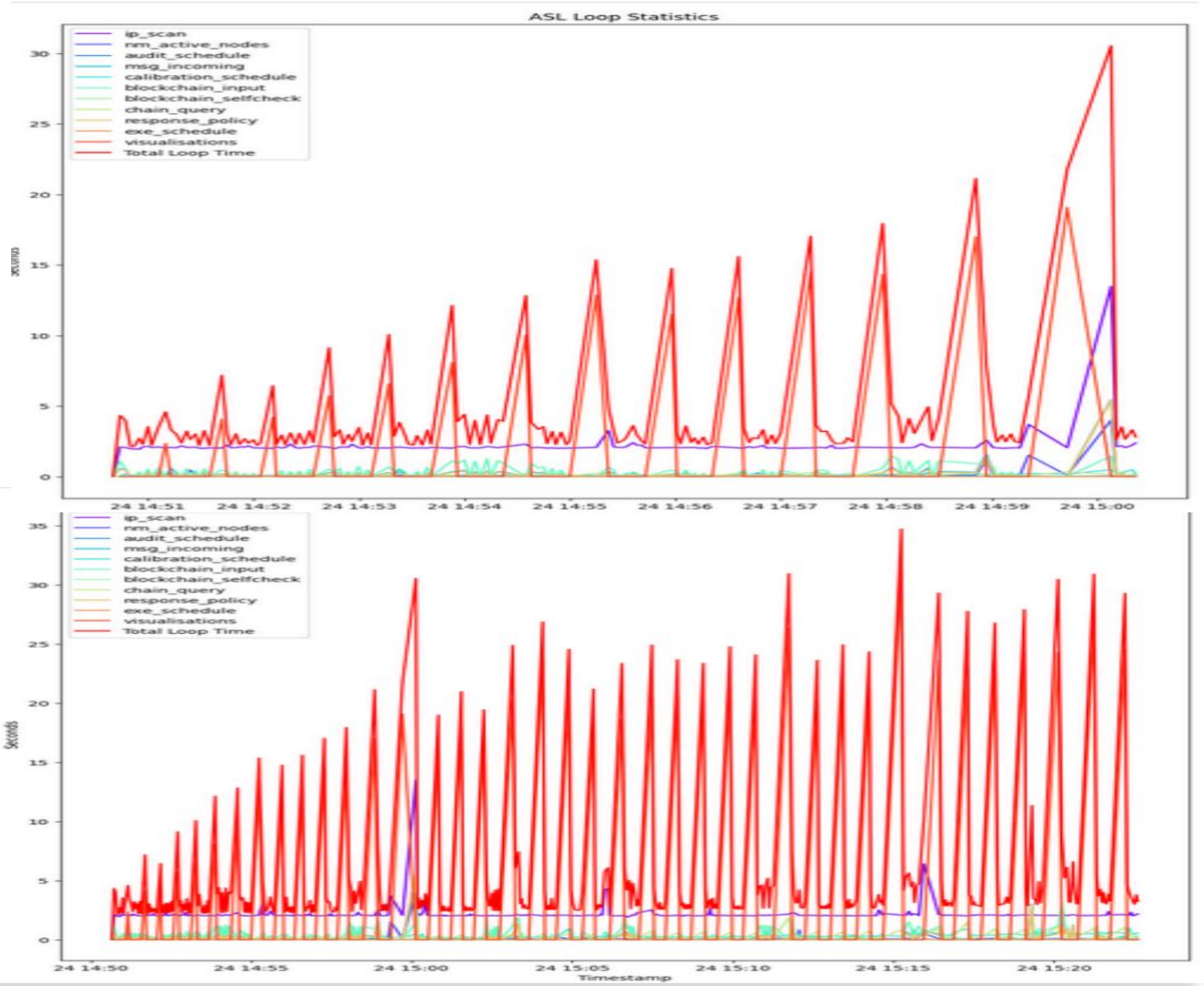
Testing

- Simulator parameters
  - Number of agents (who)
  - Number of endpoints (where)
  - Number of decisions per loop + loop delay
- Expectations
  - Stable Node communication – Issue, Maintain and Advance states with commands
  - Endpoints in system classes
  - Blockchain corroborating events
  - Planner scheduling activities

Project

Outputs

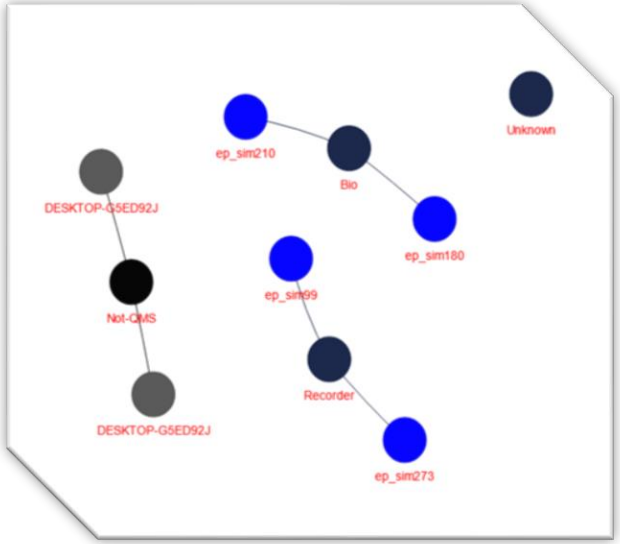
Loop Statistics

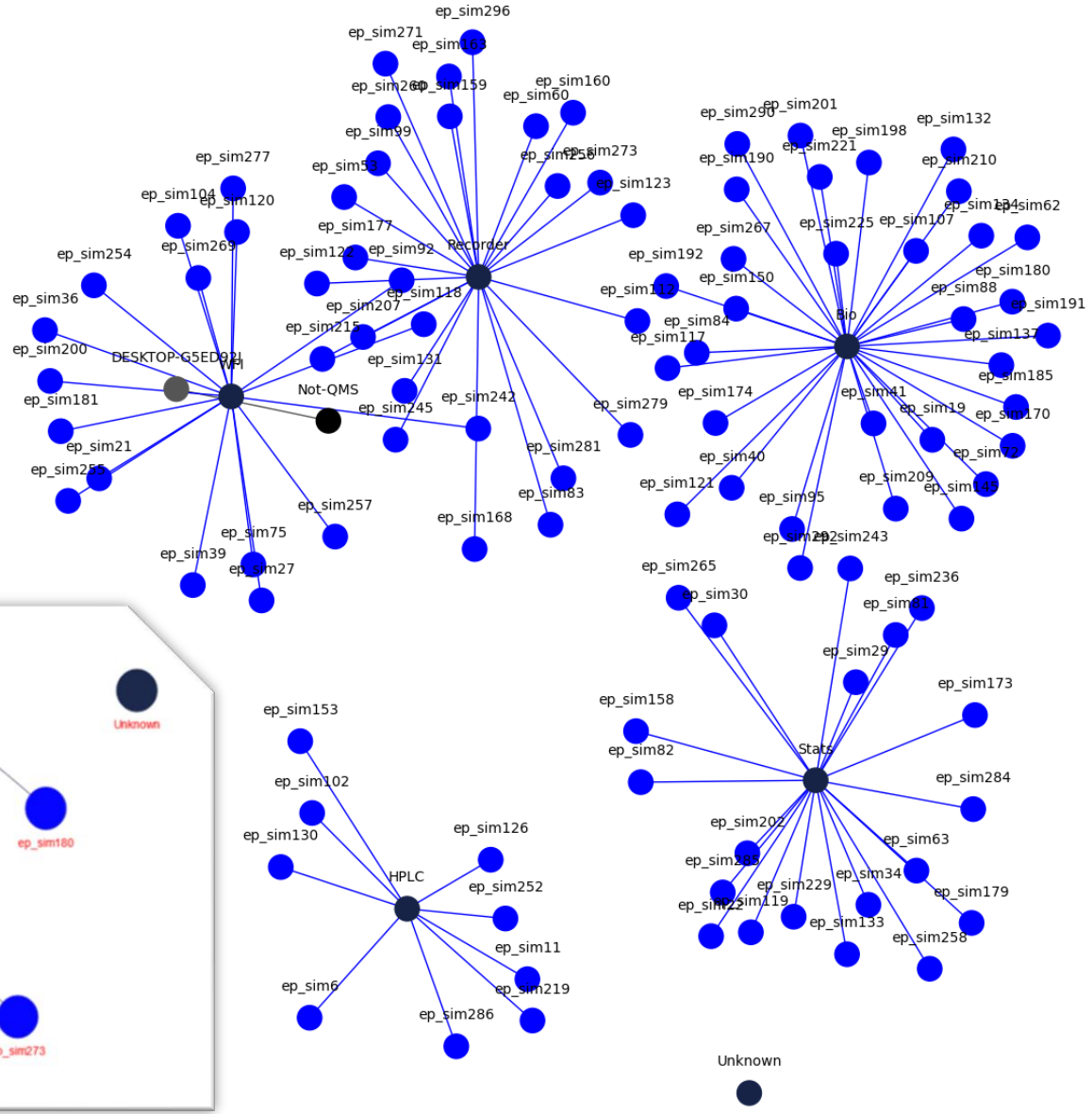


Project

Outputs

Node Class

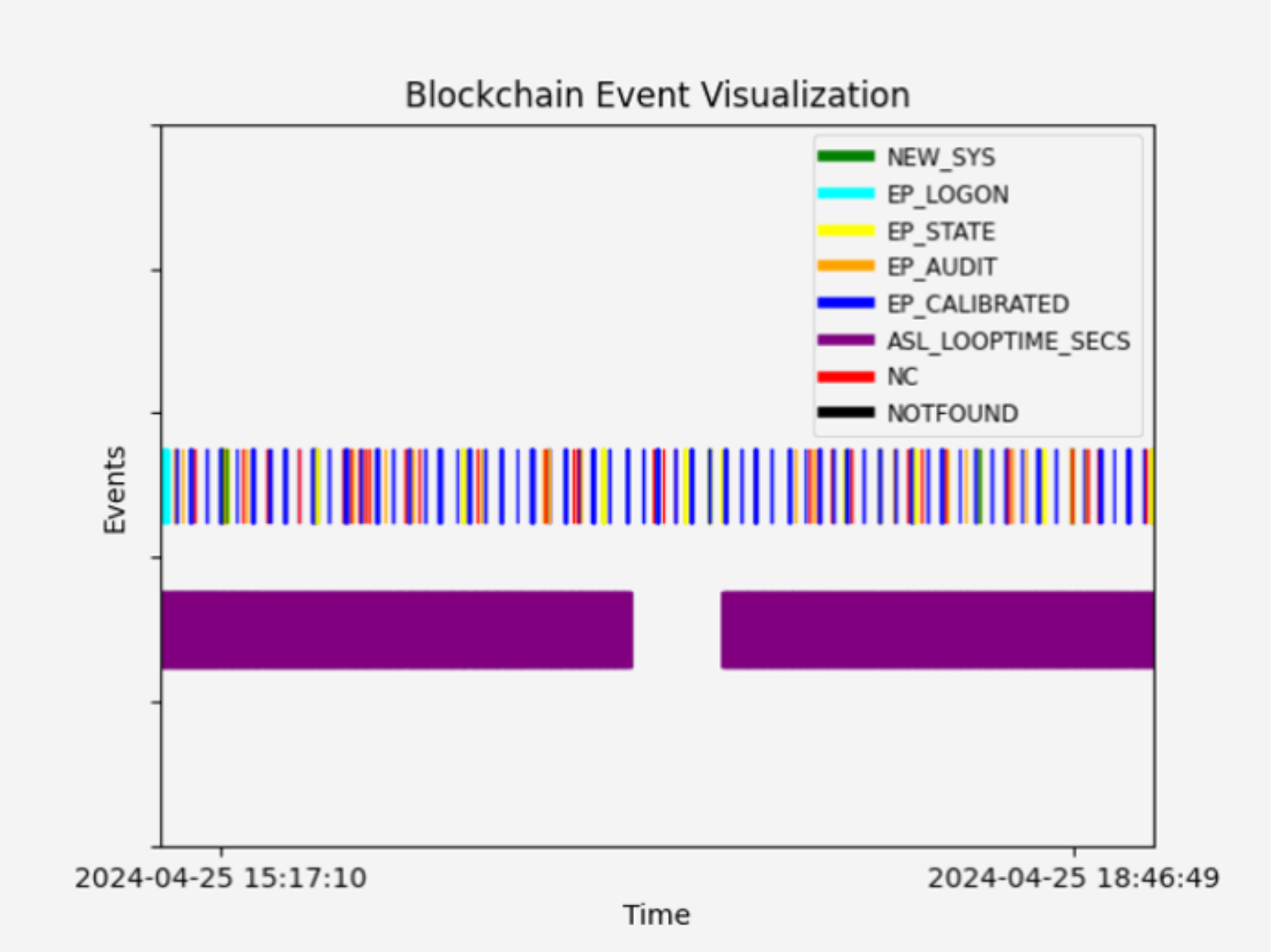




Project

Outputs

Blockchain

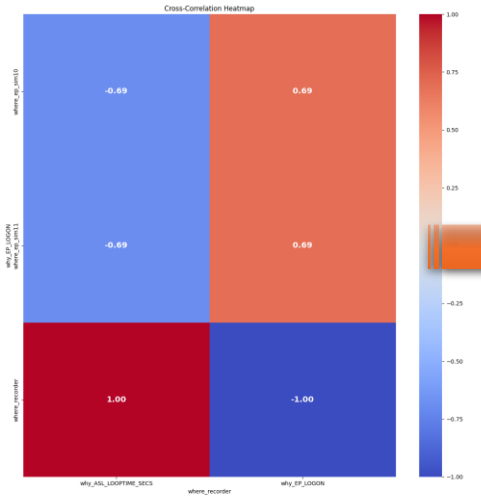


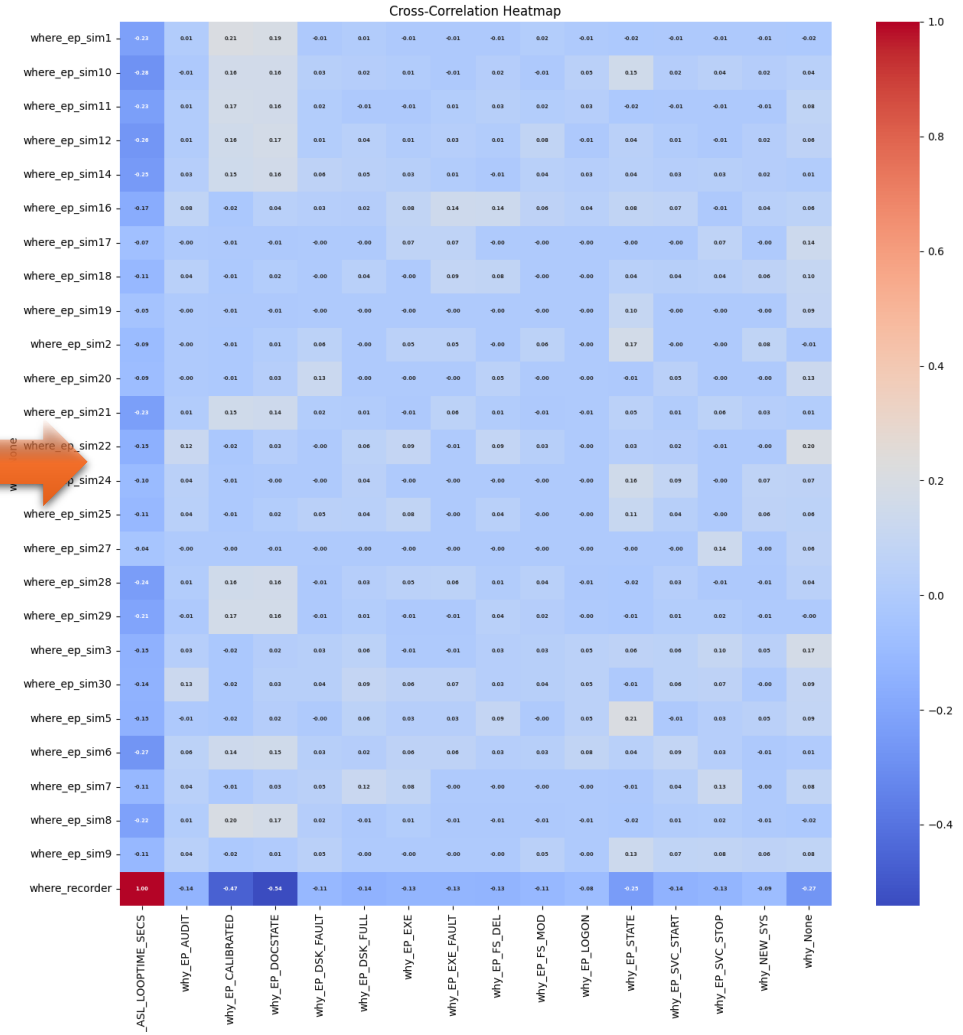
Project

Outputs

Correlations

Where - Why



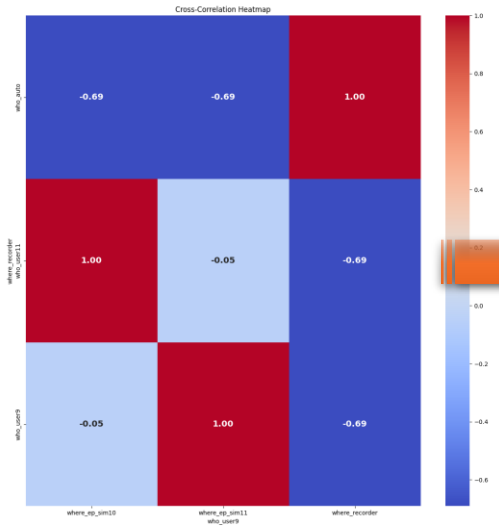


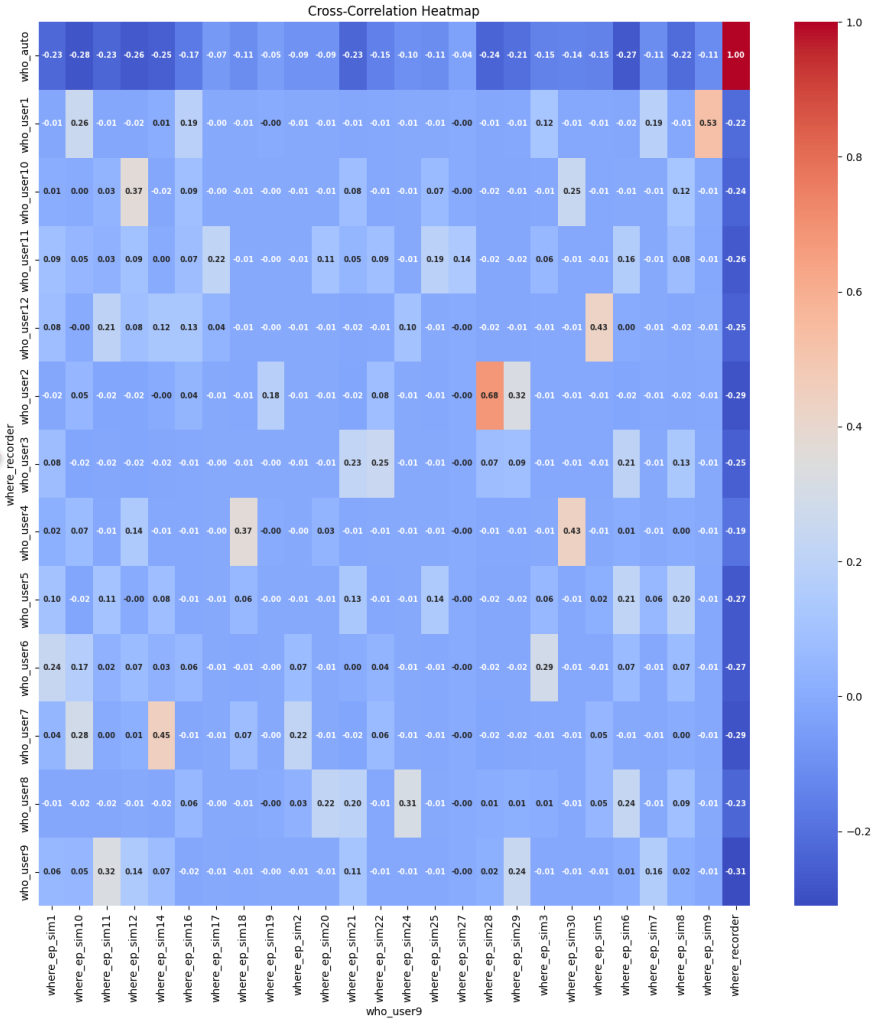
Project

Outputs

Correlations

Who - Where





Project

Conclusion

- AC Design
  - Stability and Recovery
  - Stateful QMS Endpoint Documentation

  - Blockchain: Trustworthy corroboration of events
- QMS
  - Activity captured
  - Scheduling
  - Correlation of activities
  - Human role preserved
- Potential Improvements
  - Complete AEP Functionality
  - Real/sandbox environment testing
  - AEP Auto Classification, Predictive scheduler
  - QMS Documentation Corpus

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Thank You

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