University of Siegen- Chair for Embedded Systems

Prof. Dr. –Ing Roman Obermaisser

Dr. -Ing. Daniel Onwuchekwa

Artificial Intelligent Dependable and Adaptive Autonomous Systems

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- Key Technical Progress
  - Time-triggered systems in Autonomous Operations
  - Context Information Exchange: Challenges and Approaches
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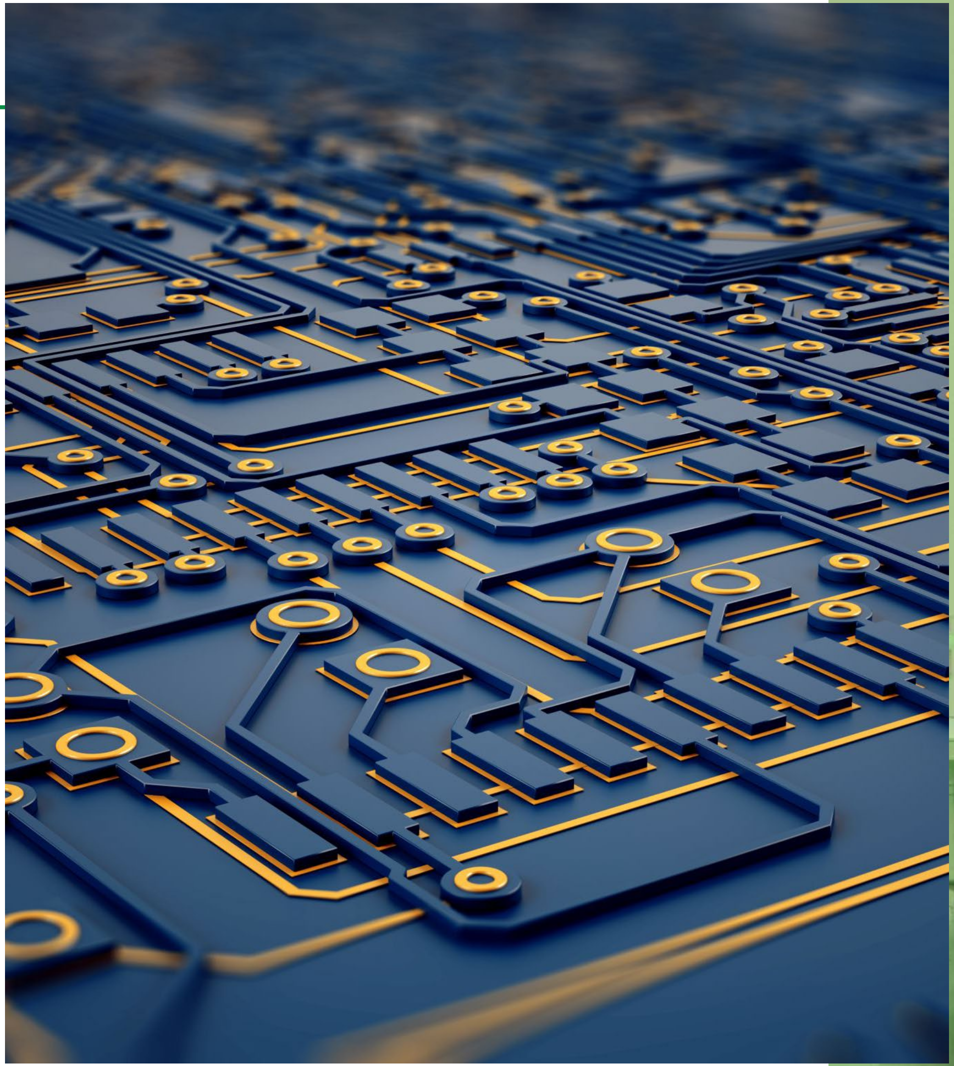
An Overview of EcoMobility's Vision and Strategy

EcoMobility : Innovating the Digital Mobility Value Chain

- Shift from individual cars to intelligent, shared transportation infrastructures.
- Importance of software and electronics in vehicle digitization.
- The emergence of a new digital mobility platform.
- Impact of AI, IoT, and robotics on transportation.
- Evolution of transportation services and functionalities.
- Coordination of varied transportation means.
- Growth of fully automated driving technologies.

EcoMobility: Challenges

- Managing more powerful hardware components.
- Exponential growth in software function complexity.
- Vehicles as 'Internet nodes on wheels'.



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EcoMobility: Vision for Sustainable Mobility

- Sustainable value chain and enabling technologies.
- Customized autonomous vehicles with agile life cycle management.
- Continuous evolution of services for improved safety and efficiency.
- User-centric approaches in vehicle functionality.

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EcoMobility: Key Innovations

- Cloud-based monitoring and coordination of vehicles.
- Energy-aware control and intelligent battery management systems.
- Safety, environment, user value, and competitiveness.
- Creating a digital mobility ecosystem.
- Benefits for society and the automotive industry.

Scope: Time-Triggered Systems: The Foundation of Reliable Control

- Time-triggered systems (TTS) are real-time systems where actions are triggered by the passage of time, not by external events. They operate on a strict schedule to execute tasks.
- **Key Characteristics**:
  - **Predictability**: Actions occur at predetermined times, ensuring consistency.
  - **Synchronicity**: Tasks across the system are synchronized, which is crucial for coordination among multiple components.
  - **Determinism**: The behavior of the system can be accurately predicted based on the time-triggered schedule.
- **Benefits**:
  - **Control of Complex Processes**: TTS can manage intricate operations by ensuring that tasks are performed in the right order and at the right time.
  - **High Reliability**: The deterministic nature of TTS minimizes the risk of errors, making it ideal for safety-critical applications like aviation control systems, automotive safety features, and industrial automation.

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Industrial Impact of Time-Triggered Systems

- **Aerospace Applications**:
  - Critical for the functionality of avionics, where each system component must operate in perfect harmony.
  - Facilitates fault-tolerant communication between control systems and sensors.
  - Example: Ensures that flight control and navigation systems receive and process data simultaneously.
- **Automotive Uses**:
  - Enhances vehicle safety features like Advanced Driver-Assistance Systems (ADAS) by providing consistent and timely sensor data processing.
  - Supports the coordination of electronic control units for better performance and safety.
- **Advantages of TTS**:
  - **Efficiency**: Saves space and power by eliminating the need for complex wiring and redundant systems.
  - **Weight Reduction**: Lighter vehicles and aircraft due to fewer physical components.
  - **Cost Savings**: Simplifies the certification process for safety-critical systems, reducing time and cost.

The need for Adaptation

- **Time-Triggered Architecture (TTA) and Its Applications**: TTA provides a framework for designing robust, predictable systems essential for aerospace and automotive industries. It ensures synchronization of operations, facilitating reliable communications and control.
- **Importance of Adaptation in Safety-Critical Systems**: Adaptation in safety-critical systems is crucial to respond to unforeseen events and maintain system integrity. It enhances resilience and helps mitigate risks associated with unexpected operational scenarios.
- **Scheduling Limitations** : Static resource allocation in TTA poses challenges in flexibility and responsiveness. It can lead to underutilization of resources or inability to cope with dynamic changes in the system environment or operational demands.

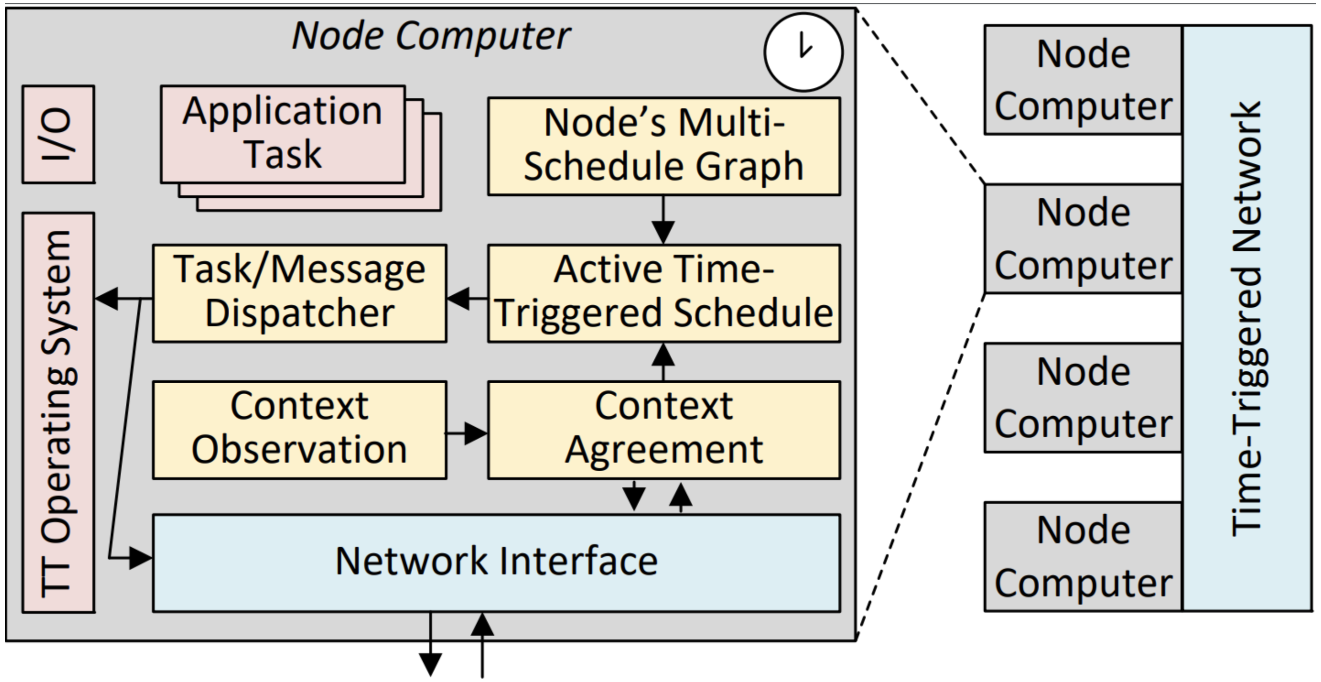
Overcoming Static Allocation in Safety-Critical Systems

- **Static vs. Dynamic Allocation**:
  - Static allocation is predetermined and unchanging, leading to inefficiencies when system demands vary.
  - Dynamic allocation adapts resource distribution in real-time, based on current demands and priorities.
- **Impact on Safety-Critical Systems**:
  - Safety-critical systems require high adaptability to respond to unpredictable changes, which static allocation cannot provide.
  - Dynamic scheduling is vital for systems where failure or inaccuracy can lead to critical outcomes.
- **The Role of Dynamic Scheduling**:
  - Necessary to handle varying operational contexts and environmental conditions.
  - Supports robust system performance by adapting to real-time changes and managing resources effectively.

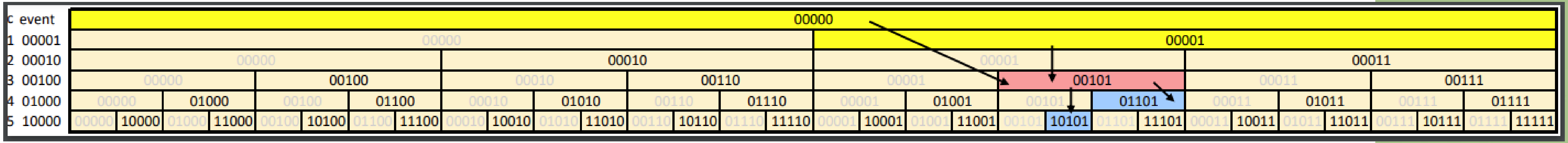
Techniques for Adaptation in TTS

- The adaptation strategies in TTS focus on reconfiguration methods ranging from local to global changes.
- To what are we adapting? - Context
- When do we adapt? - Timing
- Who is adapting? - Participants

Context Information Exchange: Challenges and Approaches



Algorithm Design for Context Scheduling



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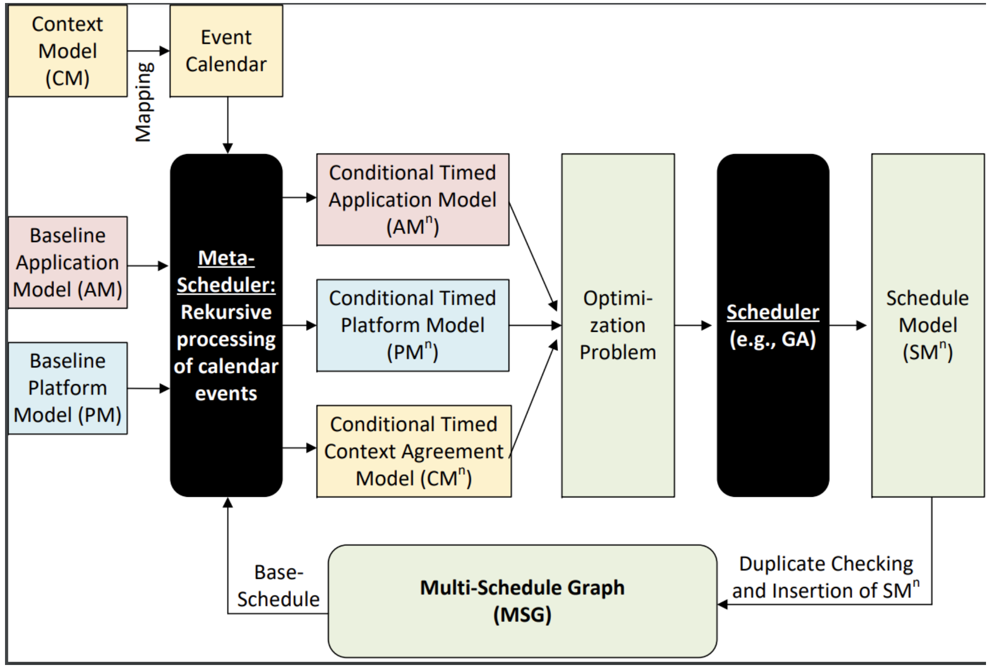
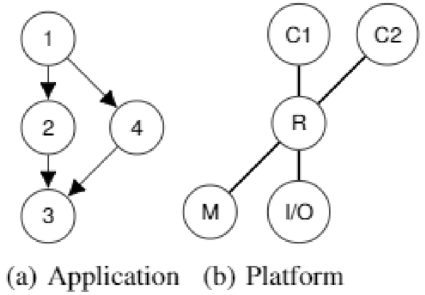


- Adaptive Time-Triggered Systems Meta-Scheduling Approach
  - Application and Platform Models
  - Context Model and Event Calendar
  - Conditional Timed Application Platform and Schedule Models



(a) Application (b) Platform

Evaluation Methodology

- Graph Generation: Utilizing Stanford SNAP Library for Directed Acyclic Graphs (DAGs) creation.
- Diverse Application Models: Job sizes from 10 to 60, different nodes, edges, indegrees, and outdegrees.
- Consistent Platform Model: For uniformity across experiments.
- Tools Used: Python DEAP library for genetic algorithm implementation.

- Evaluation Focus:
  - Communication Efficiency: Optimizing context information exchange, selective communication strategy.
  - Comparative Analysis: Comparing the new algorithm with existing methods in communication costs and system performance.

Communication Cost

- Central role in algorithm evaluation.
- Categorization of 'recipient' end systems.
  - Set of receiving end systems: Path index or ordering of a message sent by end system E_i in SM_x (Parent Schedule) is different from SM_y (Partial Child Schedule)
  - Allocated task or ordering on E_i in SM_x is different SM_y
- Context message timing exchange is resolved within the schedule.
- Communication Cost:

$$\text{Comm\_cost}/\text{Affected\_ES} = \sum_{i=1}^{n}(dx_i)$$

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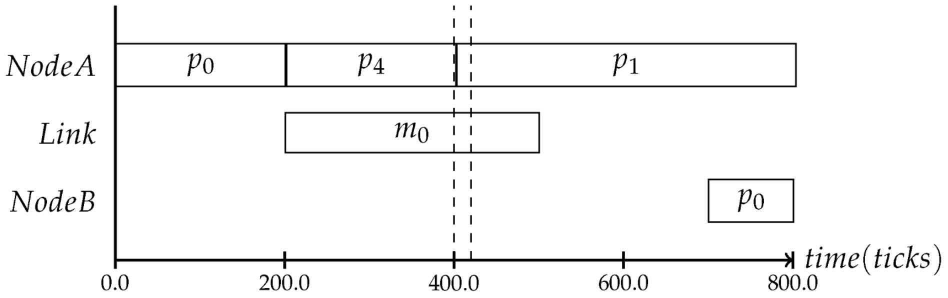
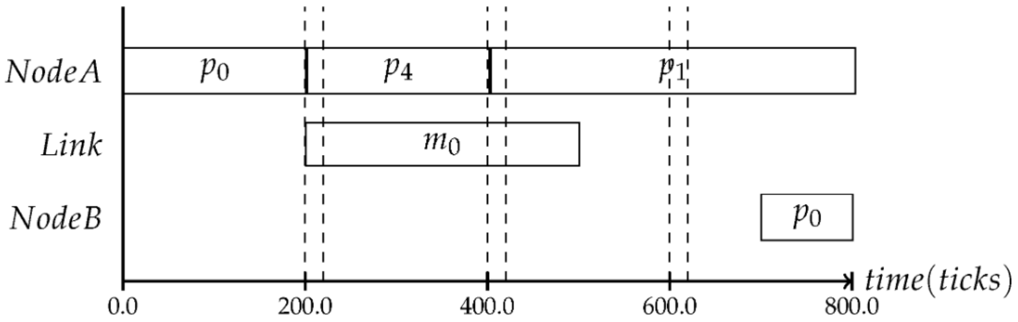
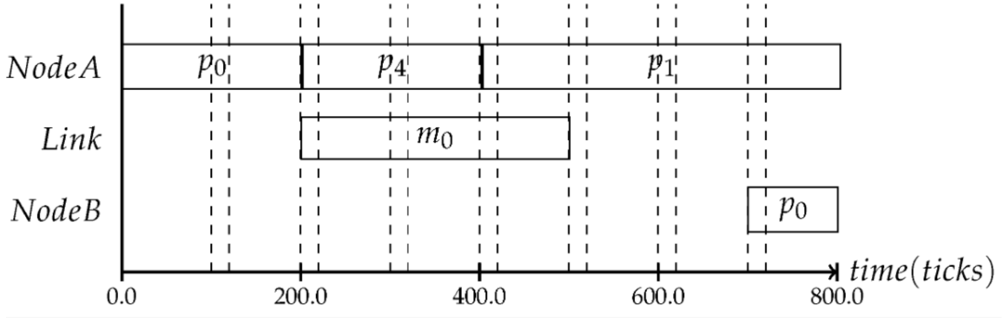
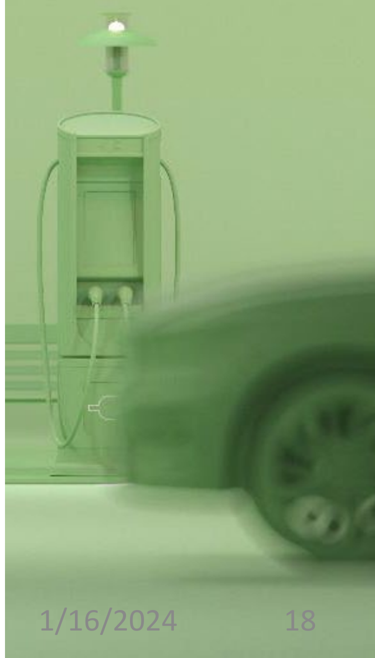
Comparison with Existing Solutions

- Comparison with standard periodic sampling methods for context information exchange.
- Simulation across varied application model profiles (10J – 60J) with intervals from 2TU (Time units) to 10TU.

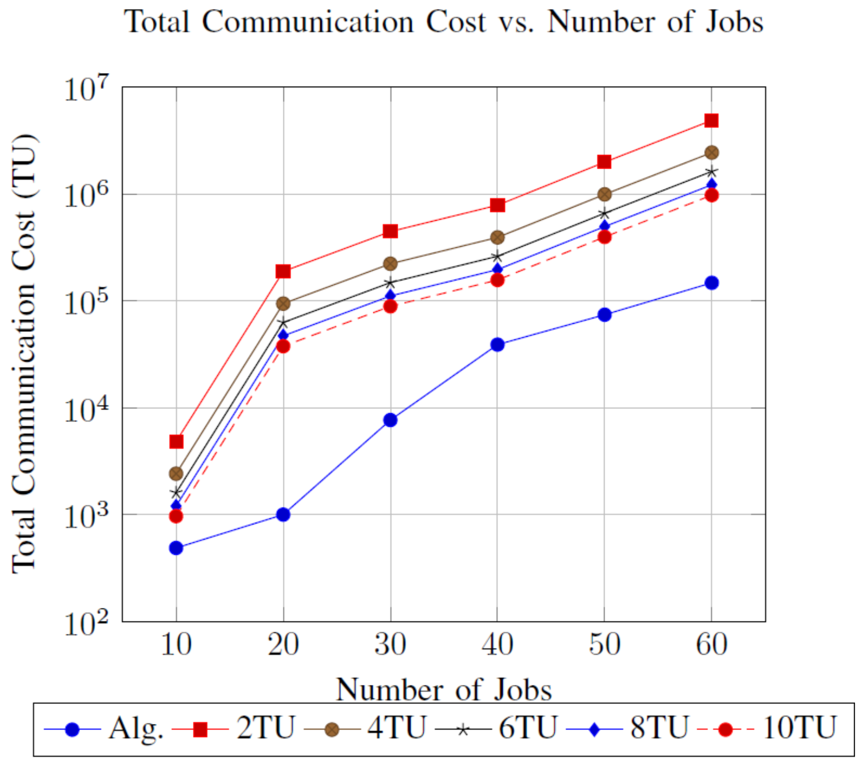


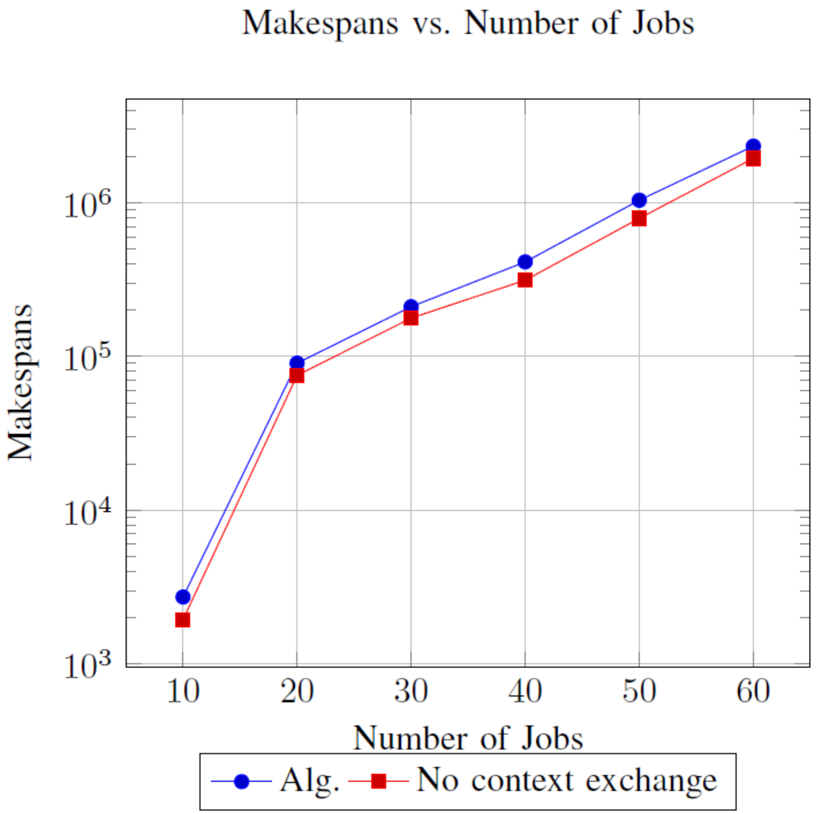






Benchmarking and Performance Analysis


Total Communication Cost vs. Number of Jobs


Makespans vs. Number of Jobs

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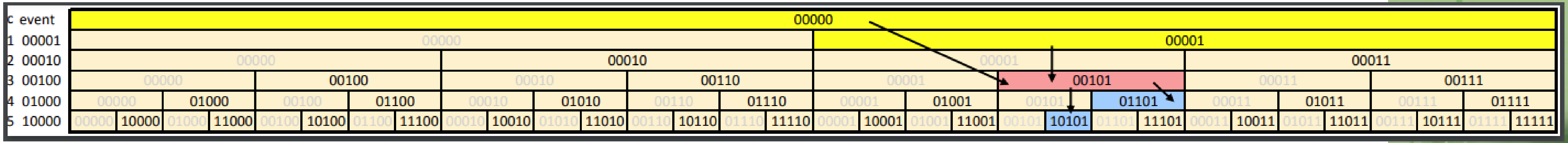
Future Directions for Dependable AI Systems

- Developed a scheduling algorithm that includes context information exchange.
- Computational load increases with more context events.
- State-space explosion issue acknowledged but not addressed in this work.
- Future research to tackle state-space explosion will consider AI algorithms.



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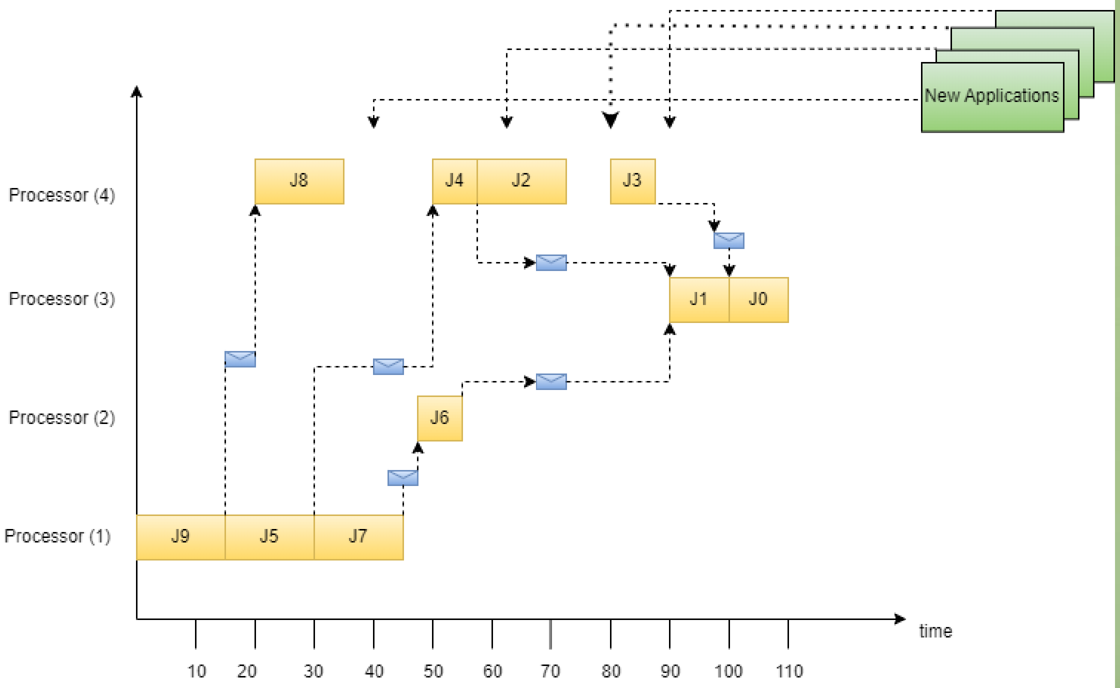
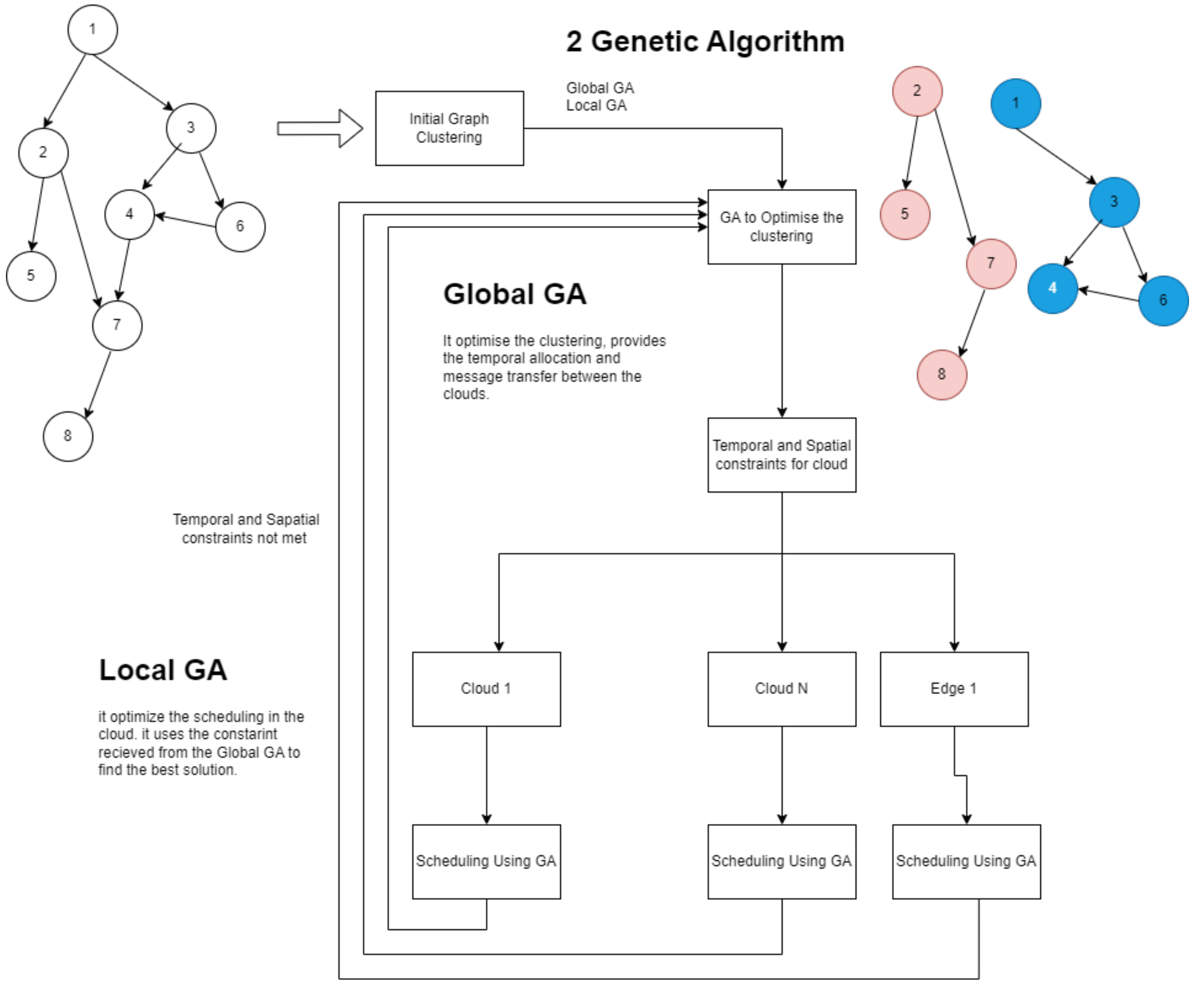
Research Plan: Incremental Scheduling – USIE

- USIE aims to develop dynamic, flexible, intelligent scheduling systems suitable for complex and evolving environments like cloud environments.
- **Developing an Incremental- scheduling technique based on a Genetic Algorithm (GA).**
    - Integrating incoming tasks directly into the ongoing scheduling processes, enhancing immediacy and adaptability.
    - Minimal changes to previous schedules, capturing the essence of incremental adjustments.
    - Multi-Environment Management: Negotiation strategies among various cloud schedulers to ensure cohesive scheduling.



USIE: Graph Partitioning



2 Genetic Algorithm

Global GA
Local GA

Global GA

It optimise the clustering, provides the temporal allocation and message transfer between the clouds.

Local GA

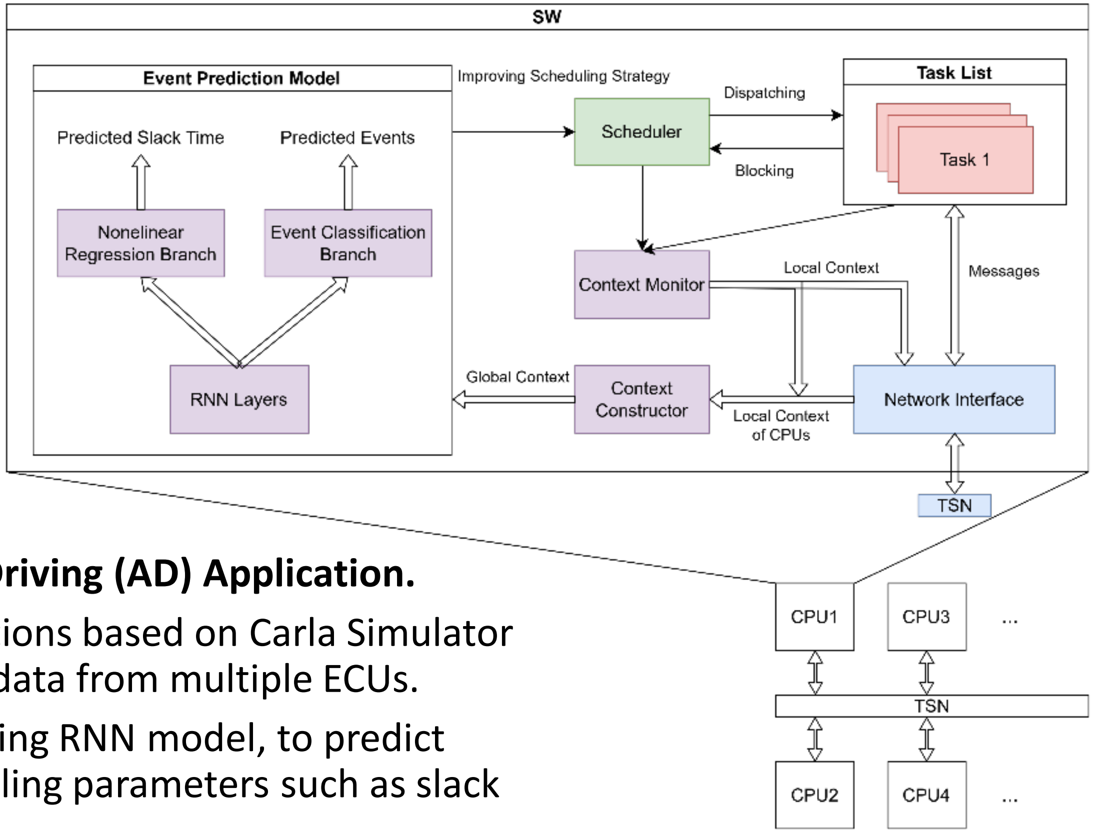
it optimize the scheduling in the cloud. it uses the constarint recieved from the Global GA to find the best solution.

- Graph partitioning in cloud-edge continuum environments helps in optimizing the allocation of computational resources.
- Ensures that computing resources are utilized effectively, reducing latency and improving overall system performance.
- By partitioning graphs intelligently, it becomes easier to scale applications horizontally, distributing the computational load across multiple edge devices and cloud servers.

- How is it Done?
  - Using Genetic Algorithm – A Global and Local One.
  - Global GA optimize the graph partitions based on the temporal constraints set.
  - Local GA allocates the task to the different processors in the cloud.
  - Additionally, a Negotiation protocol is also under development for allocating the resource in the cloud edge continuum.

Research Plan: Event Prediction Model (EPM)

- The main goal of EPM is to enhance the adaptability of time-triggered multi-core systems by intelligently adjusting scheduling strategies based on the data generated by tasks running on different processors and input from the environment.



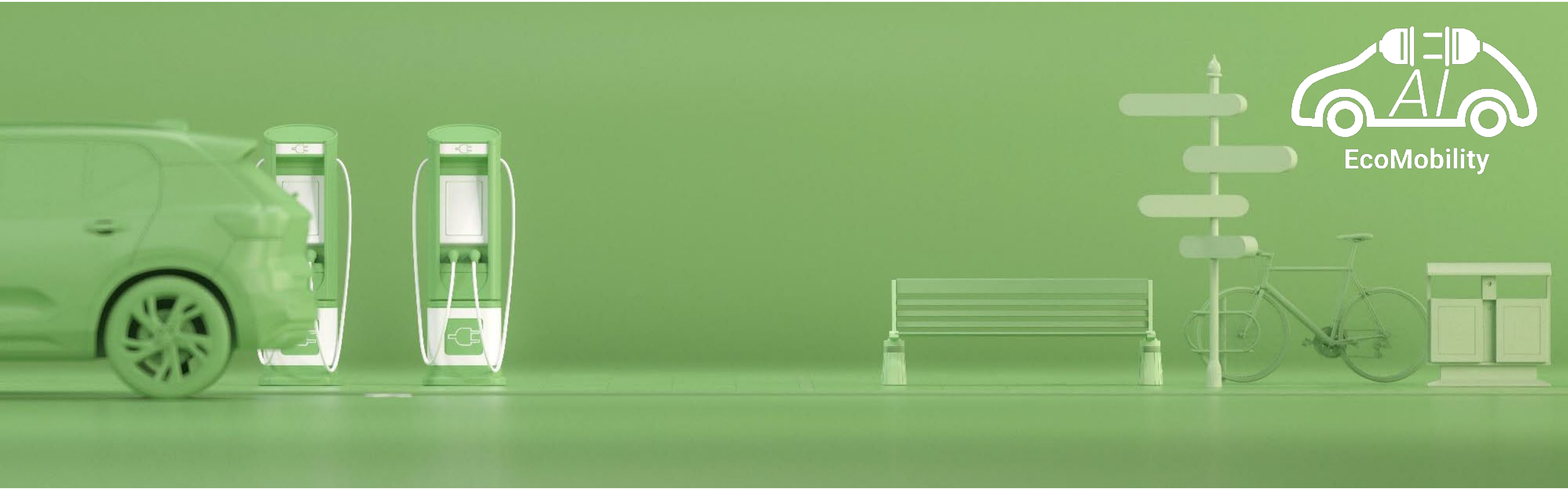
- **Developing EPM based on Autonomous Driving (AD) Application.**
    - Build autonomous driving simulations based on Carla Simulator and generate data sets based on data from multiple ECUs.
    - Develop and train EPM, multitasking RNN model, to predict contextual events and key scheduling parameters such as slack time.
    - Improve the scheduling strategy based on the prediction results.
    - Further improve EPM based on scheduling performance.

Conclusion

- Study improves adaptability in time-triggered systems for safety-critical sectors.
- Introduces a synthesis algorithm for scheduling context exchanges.
- Algorithm selectively transmits context to nodes at critical decision points.
- Significantly reduces communication overhead, optimizing system adaptability.
- Employs 'clairvoyance' for efficient, targeted communication.
- Proven to enhance communication cost and timeliness.
- Outperforms existing methods in Metascheduling for time-triggered MPSoC environments.

Thank You

The project has been accepted for funding within the Key Digital Technologies Joint Undertaking (KDT JU), a public-private partnership in collaboration with the Horizon Europe (HORIZON) Framework Programme and National Authorities under grant agreement number **101112306**



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