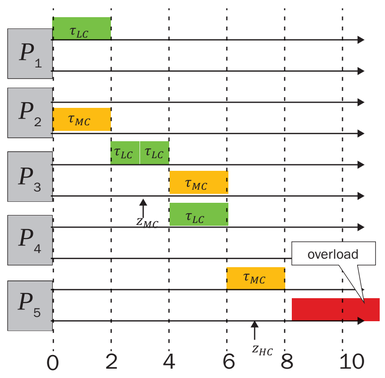
# Verifying Distributed Adaptive Real-Time (DART) Systems

## Pipelined ZSRM Scheduling

- Reduces pipeline to single-resource scheduling
- Avoids assuming worst alignment in all stages

But need to deal with transitive interferences due to zero-slack

Ongoing work: theory worked out, implementing scheduler in Linux




## Functional Verification

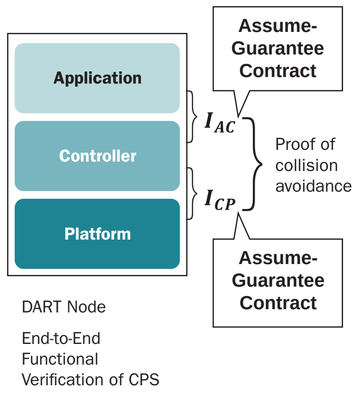
Prove application-controller contract for unbounded time

- Previously limited to bounded verification only

Prove controller-platform contract via hybrid reachability analysis

- Done by AFRL

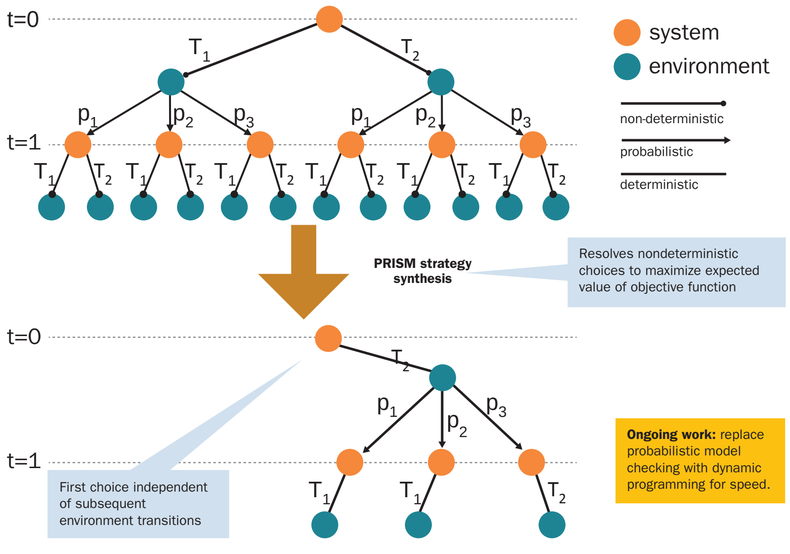
Working on automation and asynchronous model of computation




DART Node

End-to-End Functional Verification of CPS

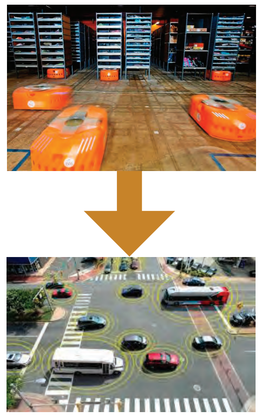
## Proactive Self-Adaptation Using Probabilistic Model Checking




## DART Vision

A sound engineering approach based on the judicious use of precise semantics, formal analysis and design constraints leads to assured behavior of (DART) systems while accounting for

- critical requirements
- probabilistic requirements
- uncertain environments
- necessary coordination
- assurance at source code level

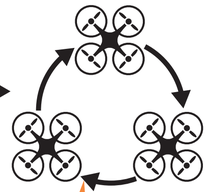


## DART Process

1. Enables compositional and requirement specific verification
2. Use proactive self-adaptation and mixed criticality to cope with uncertainty and changing context

1. ZSRM Schedulability(Timing)
2. Software Model Checking (Functional)
3. Statistical Model Checking (Probabilistic)

System + Properties (AADL + DMPL) → Verification → Code Generation



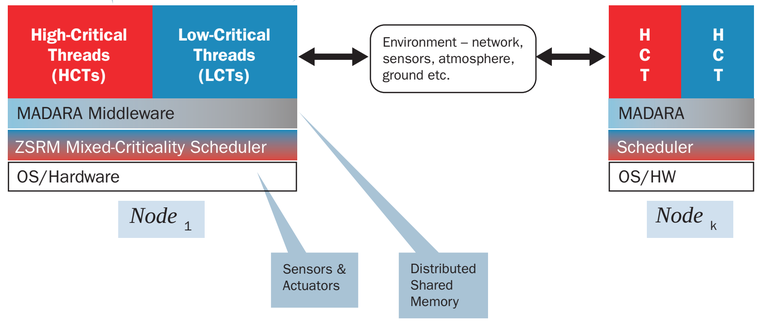
Brings Assurance to Code
1. Middleware for communication
2. Scheduler for ZSRM
3. Monitor for runtime assurance

Demonstrate on DoD-relevant model problem (DART prototype)
- Engaged stakeholders
- Technical and operational validity

## DART Architecture

Software for guaranteed requirements, e.g., collision avoidance protocol must ensure absence of collisions

Software for probabilistic requirements, e.g., adaptive path-planner to maximize area coverage within deadline

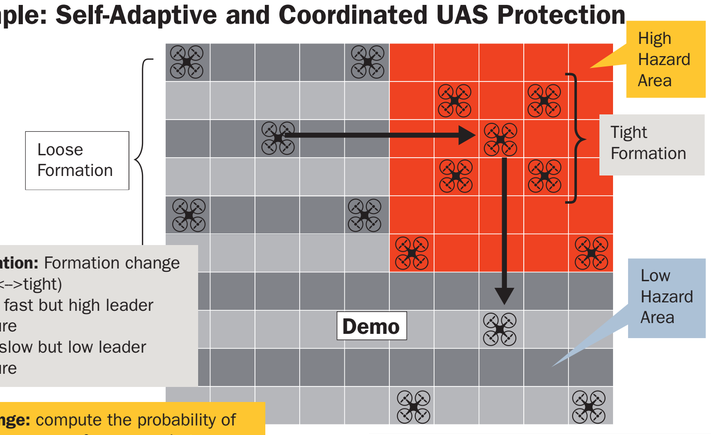



## DMPL: DART Modeling and Programming Language

- C-like language that can express distributed, real-time systems
- Semantics are precise
- Supports formal assertions usable for model checking and probabilistic model checking
- Physical and logical concurrency can be expressed in sufficient detail to perform timing analysis
- Can call external libraries
- Generates compilable C++
- Developed syntax, semantics, and compiler (dmplc)

DMPL supports the right level of abstraction. github.com/cps-sei/dart

## Example: Self-Adaptive and Coordinated UAS Protection



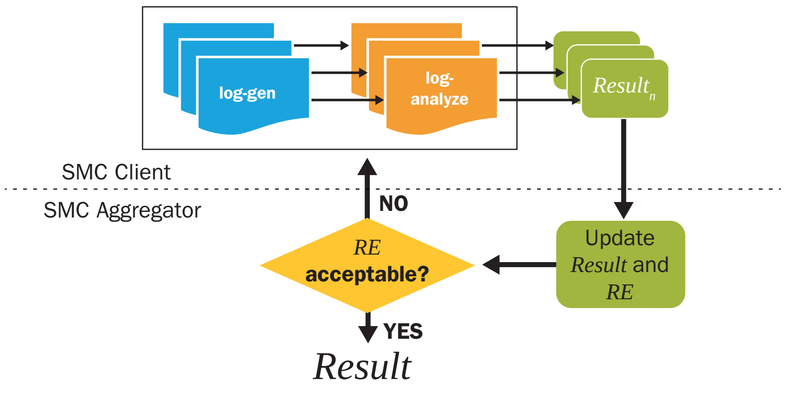

**Adaptation:** Formation change (loose<–>tight)
**Loose:** fast but high leader exposure
**Tight:** slow but low leader exposure

**Challenge:** compute the probability of mission success & compare between different adaptation strategies.
**Solution:** Statistical Model Checking

Statistical Model Checking of Distributed Adaptive Real-Time Software. David Kyle, Jeffery Hansen, Sagar Chaki.In Proc. of Runtime Verifcation 2015

## Distributed Statistical Model Checking

Batch Log and Analyze




**Future Work:** Importance Sampling to reduce number of simulations needed for "rare" events.

Each run of log-generator and log-analyzer occurs on a VM. Multiple VMs run in parallel on HPC platform. Clients added and removed on-the-fly.

**Contact: Sagar Chaki chaki@sei.cmu.edu**

This material is based upon work funded and supported by the Department of Defense under Contract No. FA8721-05-C-0003 with Carnegie Mellon University for the operation of the Software Engineering Institute, a federally funded research and development center.



DM-0002784