Center for Embedded Systems (CES)
Request for Proposals Template – YEAR 7

DUE: Wednesday, April 1, 2015, by 11 p.m.

TITLE:	Distributed run-time management for multi-agent system				
PI:	Iraklis Anagnostopoulos	**EMAIL:**	iraklisanagno@gmail.com	**TEL:**	00306948857702
DEPT:	Dept. of Electrical and Computer Engineering	**SCHOOL:**	Southern Illinois University at Carbondale		

ABSTRACT: (250 OR FEWER WORDS)

Today's prevalent solutions for modern multi-agent systems employ many processing inter-connected units leaving behind complex centralized approaches. Especially in modern automotive systems where high numbers of electronic components are employed. Navigation, car security, infotainment, travel information etc. are services highly depended on modern computing systems. In this proposed project, we couple the concept of multi-agent systems with run-time resource management techniques in order to develop a distributed framework for run-time management of multi-agent systems. The goal is to study already existing techniques, develop new solutions and implement them based on automotive constraints. The proposed framework will be based on the idea of local hypervisors and distributed agents in order to provide self-management functions while keeping system requirements.

PROBLEM:

A multi-agent system is a network of dynamic nodes, with self-configuring and self-adaptive capabilities, that interact either physically or virtually with the real world. Projections say that by the year 2020 16 billion dynamic-networked devices will be deployed, and interact with the real world simultaneously generating huge quantities of data. However, the growing complexity of these systems, due to the high number of interconnected components and complex interactions among devices, will be unmanageable, and will obstruct the development of new services and applications.

Distributed run-time management has been revealed as a key challenge to modern multi-agent systems and it has become prominent due to system's dynamicity as resources can be added or removed from such environments at any time. Traditional approaches limit scalability due to bottlenecks appeared from processing and communication functions, especially in environments that require frequent configuration changes for a big amount of agents. In this project, a framework for distributed run-time management of multi-agent systems is proposed.

RATIONALE:

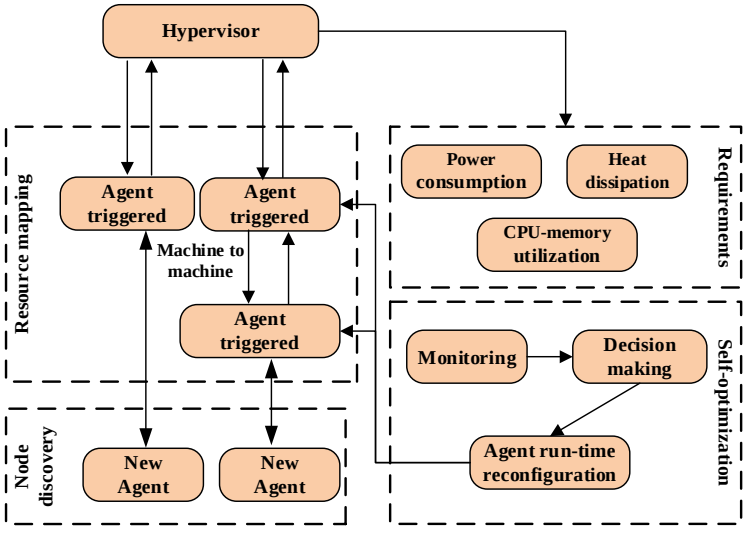
A modern vehicle is considered as a complex multi-agent system due to the high numbers of electronic components employed. In modern automotive environments, one or many embedded electronic control units (ECU) are customized both on software and hardware having fixed functionality, each handling pre-specified inputs and services. Navigation, car security, infotainment, travel information, cruise control etc. are some examples of the services highly depended on ECUs. Having, however, multiple ECUs with different non-transferable functions results in a highly failure-susceptible system with unpredictable results and once a vehicle leaves the factory, it is very difficult to apply updates in order to correct or improve specifications (fuel economy, cruise control sensitivity etc.). This is pronounced with the scalability of the interconnected components and the increased complexity in their interactions. Software errors, aging, security, legacy software, and increased performance requirements add to

the complexity in maintaining a reliable real-time system. Taking into account all the aforementioned characteristics and the specific automotive requirements such as power consumption, heat dissipation, processor and memory utilization, distributed resource management rises as the solution to these problems.

From navigation services to a "mobile" office, a modern smart-car system should be able to integrate and support also all user-end devices in an automatic and dynamic way. Thus, distributed run-time management and distributed ECUs prevail as the key technologies in order to address efficiently all the aforementioned issues. Especially nowadays that integrated multi-agent technologies software components are no longer bound to specific hardware and they can be executed on various embedded units supporting run-time service migration as well. Each embedded ECU can act as a run-time replacement for other ECUs resulting in lower susceptibility to failure.

APPROACH:

In this proposed project, we couple the concept of multi-agent systems with run-time resource management techniques in order to develop a distributed framework for runt-time management of multi-agent systems. The proposed framework will be based on the idea of local hypervisors and distributed agents in order to provide self-management functions while keeping system requirements. For example, some of the framework's distributed functionalities can include dynamic resource mapping task and management, error management, service migration etc. Certain requirements of the automotive field regarding power consumption, heat dissipation, processor and memory utilization will also be taken into consideration.



The goal of the presented framework is to adapt and evolve techniques for distributed run-time resource management coming from the many-core computing domain [6][7]. An overview of the proposed framework is depicted in Figure 1. Hypervisor is the one responsible for setting up the network and for handling all the unoccupied agents while applying application mapping techniques. Once a new application arrives on the system, the hypervisor should find available agents for serving the application. The criteria for dispatching the application will be based on certain use case requirements (workload, power consumption, temperature etc). Also, each agent should check for errors and apply self-optimization techniques offering self-management functionality to the whole system. Furthermore, constant monitoring mechanisms along with decision making techniques will make sure that system's requirements will be met. For example, whenever an agent executes tasks for a long period of time, it will be a candidate for being unoccupied for some period in order to reduce overall heat dissipation. Thus, according to the task and load distribution a "heat map" can be generated and the next task mapping should be based on power-aware criteria or a task-migration event will take place. The proposed framework will mostly focus on the run-time resource management and the distribution of the functionalities. The proposed framework will also support heterogeneous components. For example, hypervisors will be able to run complex software tasks (e.g. meta-operating system) while other agents will be just actuators executing simple tasks (e.g. sensors).

Regarding distributed run-time application mapping, state-of-art algorithms follow a divide and conquer model [6] or a role-base model as the one proposed in the project [7]. It has been shown that these algorithms can produce great results for distributed environments. Regarding the self-management process the emphasis is not on manual configuration of components, but rather on inbuilt learning and discovery capabilities [8][5]. Thus, a control-theoretic approach for automatic control is receiving increasing attention [9] having many characteristics which make it suitable for adoption within a distributed multi-agent system.

NOVELTY:

Run-time resource management and application mapping, is well recognized as an important challenge for modern systems [1][2] in general. The answer to complex multi-agent systems prevails in the autonomic computing paradigm which advocates self-adaptation [3][4]. Adaptation can be further split in self-optimization, self-healing and self-protection [5]. Last, power-aware mapping techniques [10] and power-aware memory managers [11] have greatly contributed in the overall heat dissipation and performance improvement.

The novelty of the proposed framework is threefold: (i) It integrates run-time services for multi-agent systems in a distributed way; (ii) it takes into consideration system requirements and (iii) the functionality of the system is self-managed.

POTENTIAL BENEFITS TO INDUSTRY MEMBERS:

The developed framework for distributed run-time management for multi-agent systems will be useful in many situations for the member companies. Firstly, new techniques regarding specific requirements such as power consumption and memory utilization will be evaluated. Also, the concept of multi-agent systems in modern automotive environment will be integrated and tested. Last, improvements and new solutions for self-management following the trends of a smart-car will be suggested.

DELIVERABLES:

The proposed project deliverables will be as follows:

1. Comprehensive report on the developed framework including details about the implemented algorithms and techniques. The report will also include the results regarding application and system requirements.
2. A demo with interconnected physical boards (e.g. beagleboard, raspberry pi over ethernet) of a simple scenario: Couple of nodes acting as actuators communicating with the hypervisor while executing the developed techniques.

TIMELINE/MILESTONES: (PER QUARTER)

1. Quarter 1: Study of existing techniques and selection of the appropriate methodologies-algorithms
2. Quarter 2: Define architecture and hardware specifications for hypervisor and agents.
3. Quarter 3: Development of the aforementioned framework. First ideas about demo functionality
4. Quarter 4: Finalize development, demo and report.

TECHNOLOGY TRANSFER:

Technology transfer will be performed in the form of comprehensive reports regarding power-aware memory management techniques and distributed self-management techniques for multi-agent systems.

BUDGET:

The requested budget is $50,000. The budget will cover travel expenses for meetings, acquisition of necessary equipment and salaries (PI and participating graduate students under the supervision of the PI).

BIBLIOGRAPHY: (ATTACH IN IEEE CONFERENCE OR JOURNAL FORMAT)

[1] M. Fattah et al., “Smart Hill Climbing for Agile Dynamic Mapping in Many-Core Systems,” in DAC , 2013.
[2] A. K. Singh et al., “Mapping on multi/many-core systems: survey of current and emerging trends,” in DAC , 2013
[3] Kephart J. O, Chess D.M. The Vision of Autonomic Computing. Computer, IEEE, Volume 36, Issue 1, January 2003, pp. 41-50.
[4] Dolev, Shlomi and Kat, Ronen I, Self-Stabilizing Distributed File Systems, International Workshop on Self-Repairing and Self-Configurable Distributed Systems on the 21st Symposium on Reliable Distributed Systems, October 2002, IEEE, pp. 384-390.

[5] IBM, An architectural blueprint for autonomic computing, IBM Autonomic Computing White Paper, http://www-03.ibm.com/autonomic/pdfs/ACBP2_2004-10-04.pdf
[6] I. Anagnostopoulos et al., "A divide and conquer based distributed run-time mapping methodology for many-core platforms," in DATE, 2012
[7] I. Anagnostopoulos et al., "Distributed run-time resource management for malleable applications on many-core platforms," in DAC, 2013
[8] S. White, J. Hanson, I. Whalley, D. Chess and J. Kephart, An Architectural Approach to Autonomic Computing, Proc. 1st Intl. Conf. Autonomic Computing (ICAC), IEEE, New York, May 2004, 2-9.
[9] J.L. Hellerstein, Y Diao, S Parekh, D M Tilbury. Control engineering for computing systems - industry experience and research challenges. IEEE Control Systems Magazine, Volume 25, Issue 6, Dec. 2005
[10] Siozios, K.; Anagnostopoulos, I.; Soudris, D., "A High-Level Mapping Algorithm Targeting 3D NoC Architectures with Multiple Vdd," VLSI (ISVLSI), 2010 IEEE Computer Society Annual Symposium on , vol., no., pp.444,445, 5-7 July 2010
[11] Iraklis Anagnostopoulos, Jean-Michel Chabloz, Ioannis Koutras, Alexandros Bartzas, Ahmed Hemani, and Dimitrios Soudris. 2013. Power-aware dynamic memory management on many-core platforms utilizing DVFS.

PI INFORMATION: (ATTACH 2-PAGE CV)

BIOGRAPHICAL SKETCH OF IRAKLIS ANAGNOSTOPOULOS

Assistant Professor
Department of Electrical and Computer Engineering
Southern Illinois University at Carbondale
1230 Lincoln Drive, MC 6603
Carbondale, IL 62901, USA.
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PROFESSIONAL PREPARATION

2003–2008	Diploma	Electrical & Computer Engineering	National Technical University of Athens, Greece
2008–2014	Ph.D.	Electrical & Computer Engineering	National Technical University of Athens, Greece

APPOINTMENTS

2015–date	*Assistant Professor*	Department of Electrical and Computer Engineering Southern Illinois University at Carbondale, IL, USA

PUBLICATIONS

[1] B. Candaele, D. Soudris, I. Anagnostopoulos, "Trusted Computing for Embedded Systems," *ISBN 978-3-319-09420-5, Springer*, 2014.
[2] I. Anagnostopoulos, J.M. Chabloz, I. Koutras, A. Bartzas, A. Hemani, D. Soudris, "Power-aware Dynamic Memory Management on May-core Platforms utilizing DVFS," *ACM Transactions on Embedded Computing Systems*, vol.13, no.1, pp.40:1–40:25, November 2013.
[3] K. Gyftakis, I. Anagnostopoulos, D. Soudris and D. Reisis, "A MapReduce framework implementation for Network-on-Chip platforms", *21st IEEE International Conference on Electronics, Circuits, and Systems*, Marseille France, December 2014.
[4] I. Anagnostopoulos, V. Tsoutsouras, A. Bartzas, D. Soudris, "Distributed run-time resource management for malleable applications on many-core platforms," *in Proceedings of DAC conference* 2013.
[5] I. Anagnostopoulos, A. Bartzas, G. Kathareios, D. Soudris, "A Divide and Conquer based Distributed Run-time Mapping Methodology for Many-Core platforms," *in Proceedings of DATE conference* 2012.

[6] I. Anagnostopoulos, A. Bartzas, I. Filippopoulos, D. Soudris, "High-level Customization Methodology for Application-Specific NoC Architectures," *Springer Design Automation for Embedded Systems,* vol.16, no.4, pp.339-361, 2013, doi: 10.1007/s10617-013-9114-5.

[7] I. Anagnostopoulos, S. Xydis, A. Bartzas, Z. Lu, D. Soudris, A. Jantsch, "Custom Microcoded Dynamic Memory Management for Distributed On-Chip Memory Organizations," *IEEE Embedded System Letters*, 2011.

[8] C. Silvano, W. Fornaciari, S. Crespi Reghizzi, G. Agosta, G. Palermo, V. Zaccaria, P. Bellasi, F. Castro, S. Corbetta, E. Speziale, D. Melpignano, JM. Zins, H. Hubert, B. Stabernack, J. Brandenburg, M. Palkovic, P. Raghavan, C. Ykman-Couvreur, I. Anagnostopoulos, A. Bartzas, D. Soudris, T. Kempf, G. Ascheid, J. Ansari, P. Mahonen, B. Vanthournout, "Parallel programming and run-time resource management framework for many-core platforms: The 2PARMA approach," in *Proceedings of the 6th International Workshop on Reconfigurable Communication-centric Systems-on-Chip* (ReCoSoC), 2011.

[9] A. Bartzas, P. Bellasi, I. Anagnostopoulos, C. Silvano, W. Fornaciari, D. Soudris, D. Melpignano, C. Ykman-Couvreur, "Runtime Resource Management Techniques for Many-core Architectures: The 2PARMA Approach," in *Proceedings of the International Conference on Engineering of Reconfigurable Systems and Algorithms (ERSA*), 2011.

[10] S. Xydis, A. Bartzas, I. Anagnostopoulos, D. Soudris, K. Pekmestzi, "Custom Multi-Threaded Dynamic Memory Management for Multiprocessor System-on-Chip Platforms," *in Proceedings of International Conference on Embedded Computer Systems: Architectures, Modeling, and Simulation (SAMOS)* 2010.

SYNERGISTIC ACTIVITIES

[**Research**] Iraklis' research primarily focuses in the *field of resource management for many-core systems*. Iraklis has worked in the development and use of *novel methodologies* for real-time resource management and dynamic memory management for many-core systems and *new frameworks* for platform-based application customizations. His research on run-time resource management has addressed *application self-optimization problems* for parallel application widely used for simulation of complex procedures such as thermal dissipation. Power management has also been a part of his research. Particularly, he has developed a methodology for employing intelligence power management services based on a smart decision mechanism. Iraklis has also contributed on the development of Wormsim and NOXIM system-on chip simulators providing new features and expanding its capabilities. He has served as the *Principal Investigator* for the European Union funded *TOISE: Trusted Computing for European Embedded Systems* project and he has worked as a *Researcher* for other three European Union funded projects (2PARMA, MOSART and MNEMEE)

[**Service**] (1) Participated in 5 European Union funded projects. (2) Supervised 6 students during their diploma thesis in school of Electrical & Computer Engineering, National Technical University of Athens since 2009. (3) Program Committee: SAMOS conference 2015. (3) Journal Reviewer: IEEE Trans. On Computers, IEEE Micro, ACM Trans. On Embedded Systems, Journal of Low Power Electronics, Journal of Circuits, Systems and Computers, Elsevier Microprocessors and Microsystems. (4) Keynote speaker at ATHENA summer school,

[**Honors/Award**] (1) HiPEAC Paper Award: Design Automation Conference, Austin, Texas, 2013. (2) 3*rd* Best paper award: 4th National Conference of Electrical and Computer Engineering, 2010, Patra, Greece. (3) HiPEAC Grant for HiPEAC summer school, Barcelona, Spain, 2009.

OTHER RELEVANT INFORMATION

Ph.D. Adviser: Dimitrios Soudris, School of Electrical & Computer Engineering, National Technical University of Athens, Greece.

Current Students: Mitliadis Gialousis

Past Students: Themistoklis Melissaris, Konstantinos Gyftakis, Christos Andrikos, Basilis Tsoutsouras, Georgios Kathareios, Iasonas Filippopoulos

COLLABORATORS/CO-AUTHORS

Dimitrios Soudris (ECE, NTUA), Vasileios Tsoutsouras (ECE, NTUA), Dionysios Reisis (UOA), Axel Jantsch (KTH), Zhonghai Lu (KTH), Ahmed Hemani (KTH), Kostas Siozios (ECE, NTUA), Sotirios Xydis (ECE, NTUA), Bernard Candaele (THALES), Chistina Silvano (POLIMI), William Fornaciari (POLIMI), Kiamal Pekmestzi (ECE, NTUA), George Economakos (ECE, NTUA), Jean-Michel Chabloz (KTH), Alexandros Bartzas (EXUS).

I/UCRC Executive Summary - Project Synopsis		Date: 03/31/15
Project Title: Distributed run-time management for multi-agent system		
Center/Site: Center for Embedded Systems/Southern Illinois University Carbondale		
Principle Investigator: Iraklis Anagnostopoulos		**Type: New**
Tracking No.: (CES office to input)	**Phone :** 00306948857702	**E-mail : iraklisanagno@gmail.com**
		Proposed Budget: $50,000

Abstract: Today's prevalent solutions for modern multi-agent systems employ many processing inter-connected units leaving behind complex centralized approaches. Especially in modern automotive systems where high numbers of electronic components are employed. Navigation, car security, infotainment, travel information etc. are services highly depended on modern computing systems. In this proposed project, we couple the concept of multi-agent systems with run-time resource management techniques in order to develop a distributed framework for run-time management of multi-agent systems. The goal is to study already existing techniques, develop new solutions and implement them based on automotive constraints. The proposed framework will be based on the idea of local hypervisors and distributed agents in order to provide self-management functions while keeping system requirements.

Problem: The growing complexity of multi-agent systems, due to the high number of interconnected components and complex interactions among devices, will be unmanageable, and will obstruct the development of new services and applications. Distributed run-time management has been revealed as a key challenge to modern multi-agent systems and it has become prominent due to system's dynamicity as resources can be added or removed from such environments at any time.

Rationale / Approach: A modern vehicle is considered as a complex multi-agent system due to the high numbers of electronic components employed. In modern automotive environments, one or many embedded electronic control units (ECU) are customized both on software and hardware having fixed functionality, each handling pre-specified inputs and services. Navigation, car security, infotainment, travel information, cruise control etc. are some examples of the services highly depended on ECUs. Thus, distributed run-time management and distributed ECUs prevail as the key technologies in order to address efficiently all problems generated by system's complexity. In this proposed project, we couple the concept of multi-agent systems with run-time resource management techniques in order to develop a distributed framework for runt-time management of multi-agent systems. The proposed framework will be based on the idea of local hypervisors and distributed agents in order to provide self-management functions while keeping system requirements.

Novelty: The novelty of the proposed framework will be threefold: (i) It will integrate run-time services for multi-agent systems in a distributed way; (ii) it will meet system requirements and (iii) it will provide a self-management functionality in the system.

Potential Member Company Benefits: The developed framework for distributed run-time management for multi-agent systems will be useful in many situations for the member companies. Firstly, new techniques regarding specific requirements such as power consumption and memory utilization will be evaluated. Also, the concept of multi-agent systems in modern automotive environment will be integrated and tested. Last, improvements and new solutions for self-management following the trends of a smart-car will be suggested.

Deliverables for the proposed year: I) Comprehensive report on the developed framework, II) Demo, with interconnected physical boards (e.g. beagleboard, raspberry pi over ethernet) of a simple scenario.

Milestones for the proposed year:
Quarter 1: Study of existing techniques and selection of the appropriate methodologies-algorithms
Quarter 2: Define architecture and hardware specifications for hypervisor and agents.
Quarter 3: Development of the aforementioned framework. First ideas about demo functionality
Quarter 4: Finalize development, demo and report.

Progress to Date:

Estimated Start Date: 08/16/2015	**Estimated Knowledge Transfer Date**: 08/31/2016