Towards a Time-Constrained Service-Oriented Architecture for Automation and Control in Large-Scale Dynamic Systems

Gang Chen, Baoran An

Institute of Computer Application, China Academy of Engineering Physics, Mianyang, China

INTRODUCTION

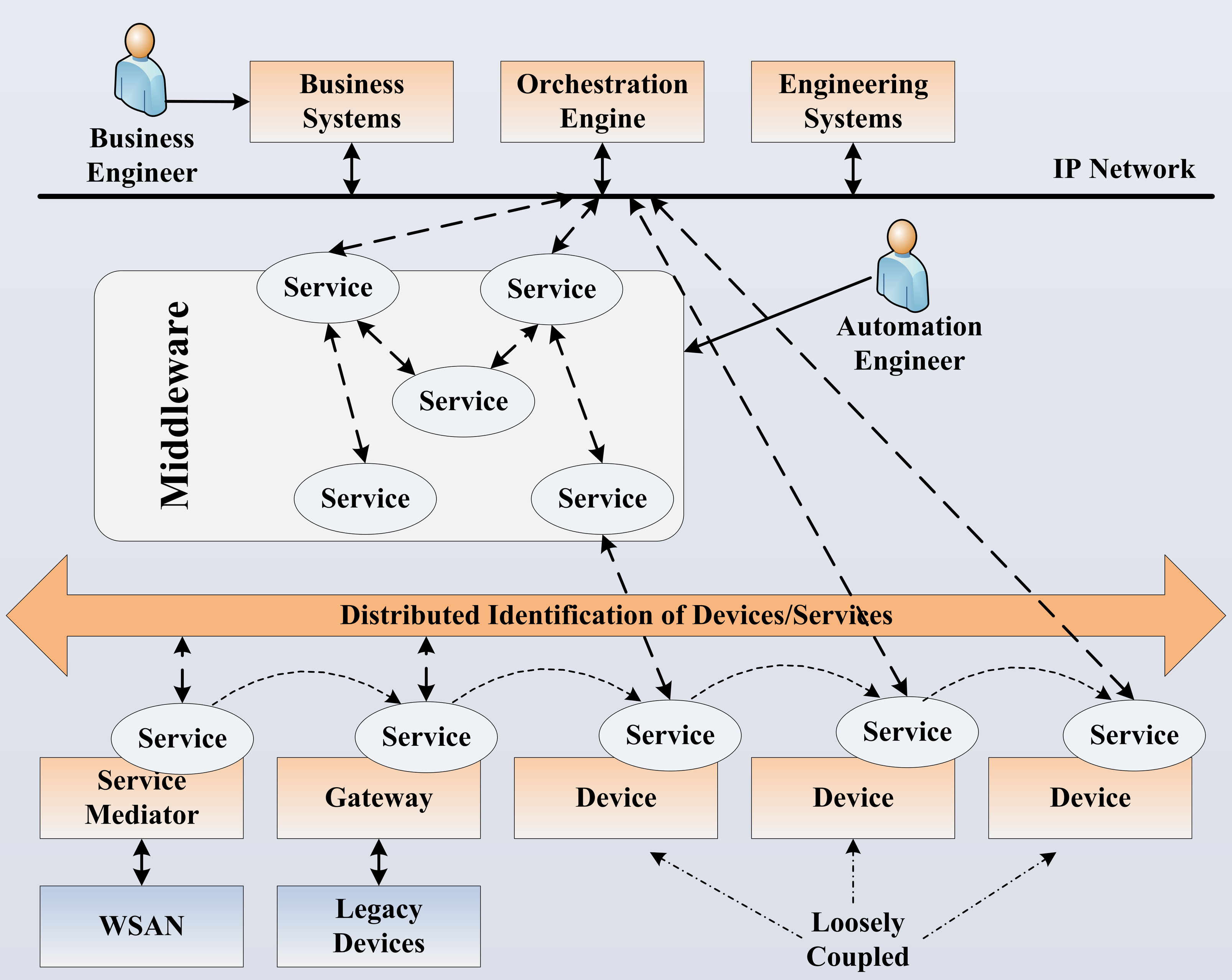
Rapidly changing demands for interoperability among heterogeneous systems leads to a paradigm shift from pre-defined control strategies to dynamic customization within many automation systems, e.g., large-scale scientific facilities. However, today's mass systems are of a very static nature. Fully changing the control process requires a high amount of expensive manual efforts and is quite error prone. Hence, flexibility will become a key factor in the future control systems. The adoption of web services and Service-Oriented Architecture (SOA) can provide the requested capability of flexibility. Since the adaptation of SOAs to automation systems has to face time-constrained requirements, particular attention should be paid to real-time web services for deterministic behaviour. This paper proposes a novel framework for the integration of a Time-Constrained SOA (TcSOA) into mass automation systems. Our design enables service encapsulation in filed level and evaluates how real time technologies can be synthesized with web services to enable deterministic performance.

In this paper, our contributions are as follows:

1. we present a web service communication policy for non-standard application requirements.
2. A Time-Constrained Service-Oriented Software Architecture (TcSOA) is outlined that supports the convergence of heterogeneous automation layers.

Device-Centric SOA in Large Scale Systems

In device-centric automation systems, the services represent the functionalities of individual devices or processing modules, like simulating cells. The behaviour of the overall system is controlled by the coordination of all services. Due to independency and interoperation of services, the device-centric systems can be arranged by sequence-controlled services, which imply that reengineering effort for modifying existing automation structures can be minimized. Whereas the components of current big systems are interconnected and tightly-integrated, the automation engineers have to deal with any tiny modification with much manual effort, even in the initial setup stage of a system. Furthermore, such type of composition must be guaranteed by an orchestration engine, which provides particular strategies to composite services, schedule the controlled services and to move up the newly composed service sequence to a higher layer.



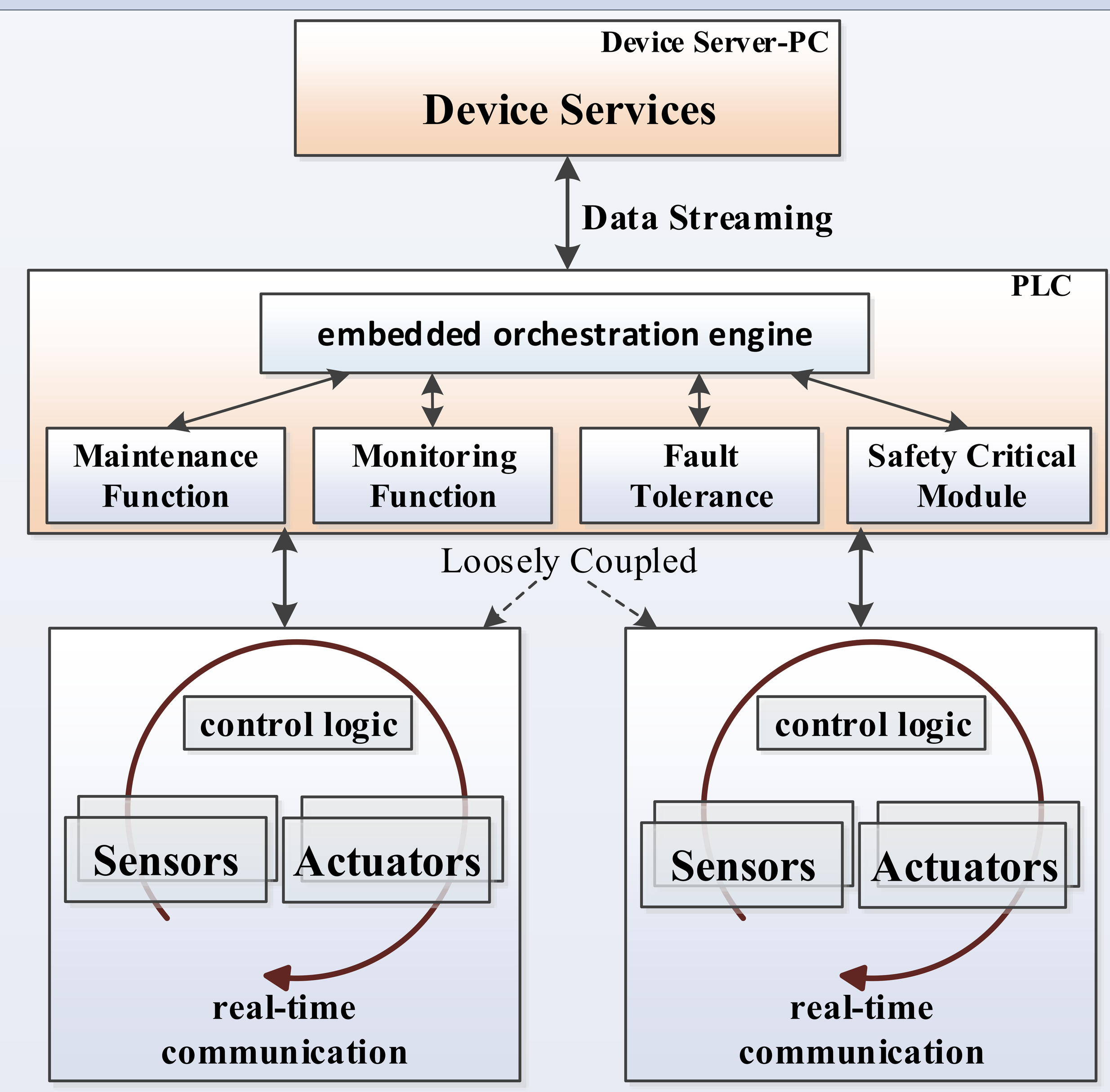
Defining a web service communication policy

In time-constrained SOA, service providers can enable real-time services, i.e. invocations of services must be completed within specific timing constraints. As well, in device-centric SOA environment, the device producers can provide services that follow time-constraint requirements. Besides that, all operations in systems that are facilitated by SOA have to abide by time-constraints.

The first scenario is to examine the communication between individual services. Since services might exist in different remote nodes, the real-time communication is a critical issue that needs to resolve to achieve the objectives of TcSOA. We have analysed different setups with service communication to identify which parts could be omitted to reduce time requirements. Basically, messaging techniques are the most important parts of service communication implementations. Firstly, messages to be exchanged between services need to be serialized in real-time for marshalling/unmarshalling; The resource requirements, such as channel bandwidth and CPU time, need to be reserved. Because the messages may cross over multiple layers and corresponding protocols, a service can provide various levels of messages. Regardless of which level, a time-constrained message should possess the following characteristics:

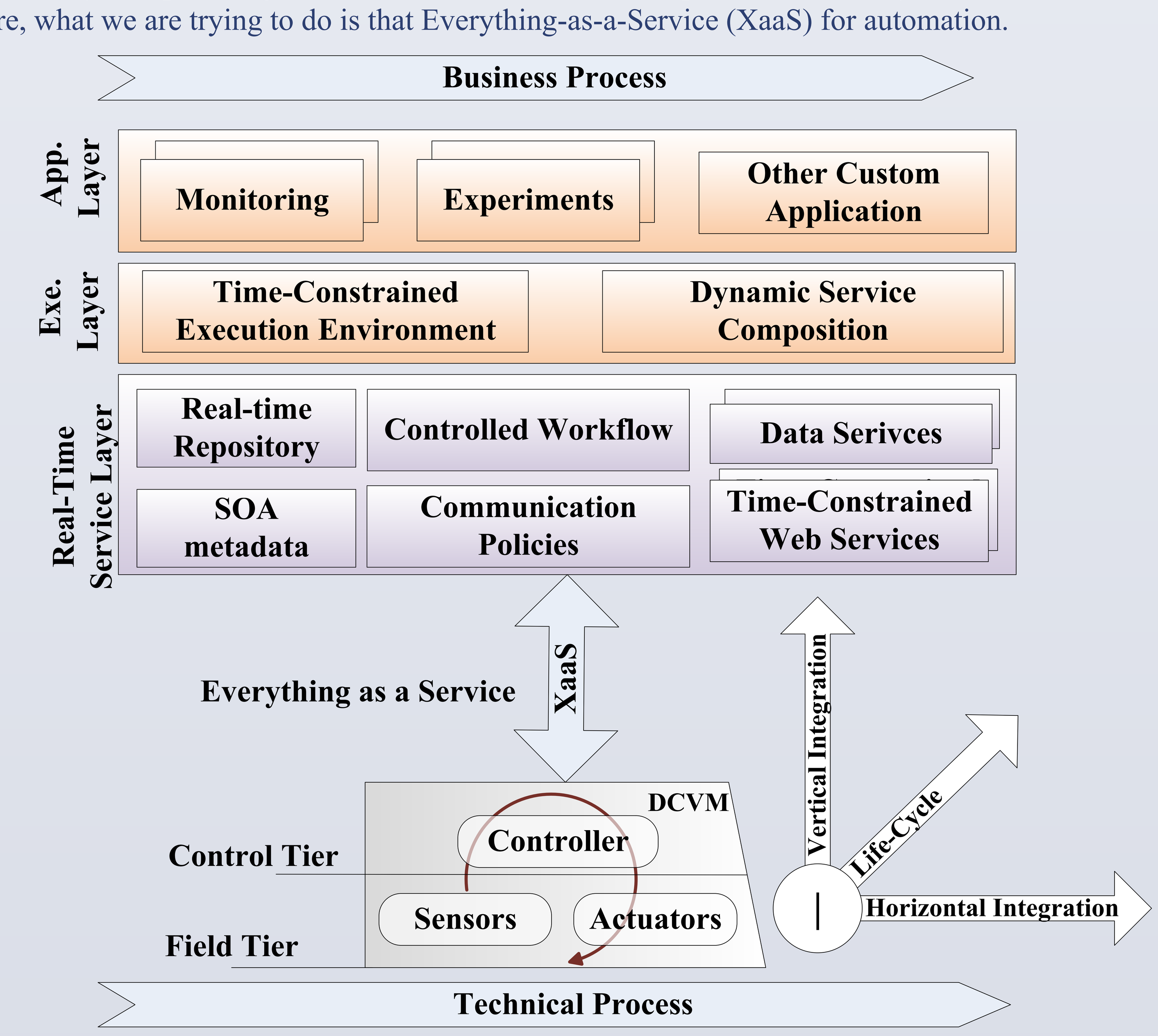
- Limited response time set, like the minimum and maximum response time
- Recovery strategies (such as message retransmission mechanisms)
- Maximum data capacity
- Degree of concurrency, like the maximum number of receivers that the message is sending to
- Cost and required resources

Here, we propose a novel concept Device-Cluster-Virtual-Module (DCVM) to instead of the concept of individual device. A DCVM is a small group of physical tightly-coupled devices, which can provide some functionality to the outside world. Within a DCVM, the devices are interconnected via real-time communication based industrial data bus like field bus. That means, inside the DCVM, all devices are tightly-coupled while DCVMs are loosely-coupled between each other. In order to control the behaviours of the devices and data processing, an embedded orchestration engine is integrated in each DCVM, which provide control logic by automation engineers for device communication and management.



System Architecture

The system architecture integrates time-constrained web services and consists of four functional layers – application layer, execution layer, real-time service layer and hardware layer – which contain several components to meet the demands of web service based automation systems. The integration of devices and standard services will be enabled by encapsulating functions inside communication policies. Generally, in this envisioned architecture, what we are trying to do is that Everything-as-a-Service (XaaS) for automation.



REFERENCES

[1]L. Duerkop, H. Trsek, J. Otto and J. Jasperneite, "A Field Level Architecture for Reconfigurable Real-time Automation Systems", in *Proc. WFCS*, 2014.

[2]H. ElMaraghy and H. –P. Wiendahl, "Changeability- An Introduction", *Changeable and Reconfigurable Manufacturing Systems and Transformable Factories'09* , pp. 1-24.

[4]I. M. Delamer and J. L. M. Lastra, "Loosely-Coupled Automation Systems Using Device-Level SOA", in *Proc. Int. Conf. on Industrial Informatics*, 2007, pp. 743-748.

[5]Lars Duerkp, Juergen Jasperneite and Alexander Fay, "An analysis of Real-time Ethernets with Regard to Their Automatic Configuration", in *Proc. World Conf. on Factory Communication Systems (WFCS)*.

[6]M. Wollschlaeger, T. Sauter, and J. Jasperneite, "The future of industrial communication: Automation networks in the era of IoT and Industry 4.0", *Ind. Electron. Mag.*, vol. 11, no.1, 2017, pp. 17-27.

[7]M. Loskyll, J. Schlick, S. Hodek *et al*, "Semantic service discovery and orchestration for manufacturing processes", in *Proc. Int. Conf. on Emerging Technologies and Factory Automation* , 2011.

[8]M. Gudgin *et al*, "SOAP Version 1.2 Part 2: Adjuncts", June 2003.[online] Available: http://www.w3.org/TR/soap12-part2/.

[9]Apache Axis 2, http://ws.apache.org/axis2/

[10]WSDL, https://www.w3.org/TR/

[11]R. High, S. Kinder, S. Graham, "IBM's SOA Foundation: An Architecture Introduction and Overview", 2005.11.

[12]W. T. Tsai, Y. –H, Lee and Z. Cao, "RTSOA: Real-time service-oriented architecture", in *Proc. Int. Symp. on Service-Oriented System Engineering*, Washington, DC, Oct. 2006, pp. 49-56.

[13]M. –T. Schmidt *et al*, "The Enterprise Service Bus: Making Service-Oriented Architecture Real", IBM System Journal 44, no. 4, 2005, pp. 781-798.

[14]M. G. Valls, I. R. Lopez, I. F. Villar, "iLand: an enhanced middleware for real-time reconfiguration of service oriented distributed real-time systems", IEEE Trans. on Industrial Informatics, vol. 9(1), pp. 228-236, 2013……

ACKNOWLEDGMENT

This work is supported by National Natural Science Foundation of China(61333003) and Science and Technology Development Foundation of China Academy of Engineering Physics (14-FZJJ-0422). The authors would like to thank the participants in the user studies for their time and valuable insight.