

CPS/IoT Ecosystem

Preparing Austria for the next digital revolution

Looking back at the time Bill Gates was one of his brilliant students, Christos Papadimitriou a Harvard professor and world-renowned computer scientist, concluded that one of the great challenges of the academic community is to recognizing when an IT revolution is on its way. He did not see the PC revolution coming, but his student did. Since then several others happened, and a new one is in the making: The CPS/IoT revolution.

The Austrian academic institutions have a responsibility to ask the following main questions: Are we prepared for the CPS/IoT revolution? Do we have the proper infrastructure, software tools and courses? The answer is unfortunately NO and we have to act NOW!

Cyber-physical systems (CPS) are spatially-distributed, time-sensitive, multiscale networked embedded systems, connecting the physical world to the cyber world through sensors and actuators. The Internet of Things (IoT) is the backbone of CPS. It connects the Sensors and Actuators to the nearby Gateways and the Gateways to the Fog and the Cloud. The Fog resembles the human spine, providing fast and adequate response to imminent situations. The Cloud resembles the human brain, providing large storage and analytic capabilities.

CPS research is strongly anchored within academia. For example, we teach two graduate CPS courses at TUW: The Logical- and The Stochastic-Foundations of CPS. There are also many CPS conferences worldwide. For example, we hosted this year in Vienna CPS-Week, the premier event in CPS, with a large scientific and industrial participation.

IoT research however, was mostly ignored in academia. Not so in industry! With a forecast of 50-bn devices connected by 2020 and \$15-trn business in next 20 years, all big industrial players are dedicating vast resources to IoT. In the US alone, Amazon, Apple, Cisco, General Electric, Google, IBM, Intel, Microsoft and many others compete for a piece of the IoT. In Germany, Bosch, Kuka, Siemens, Telekom, etc. In Austria we have TTTech, Infineon, ams, and others. CEOs of most of these companies will talk at this year's IoT World Congress, but almost no academic researcher. This will change for sure. For example, next CPS-Week event will include an IoT conference, too.

Four pillars drive industrial forecasts: Connectivity, Monitoring, Prediction, and Optimization. First two are already in progress, enabled by recent technological advances. Last two are expected to radically change our society. The huge number of sensors to be deployed in manufacturing, transportation, energy and utilities, buildings and urban planning, health care, environment, or jointly in smart cities, will allow the collection of terabytes of information (Big-Data), which can be processed for predictive purposes. Moreover, the huge number of actuators will enable the optimal control of these areas and drive market advantages. For example, the predictive maintenance of assets is expected to save up to 12% in scheduled repairs, reducing maintenance costs up to 30%, and eliminating breakdowns up to 70%¹.

According to GE's report, 73% of companies are already investing more than 25% of their technology budget in big-data analytics. Moreover, ¾ of executives expect that level to increase just in the next year. Across the industries surveyed, 80% to 90% of companies indicated that big-data analytics is either the top priority (61% in aviation industry) or in the top three (28% for power distribution, 31% for power generation, 31% for oil and gas, 24% for mining). In 53% of companies the board of directors is the primary influencer of their IoT adoption strategy. Strong board-level support can also be seen in manufacturing (67%), rail (60%) and wind (45%). A staggering 89% say that companies not adopting IoT and big-data analytics in the next year risk losing market share and momentum.

¹ GE IoT Report: <http://www.ge.com/digital/sites/default/files/industrial-internet-insights-report.pdf>

Realization Concept

Goals: As the above executives, we strongly believe that there is a great risk for the Austrian society in not taking a swift action now. Without an active participation in CPS/IoT revolution the Austrian companies will lose confidence in their ability to grow and the companies of other countries will gain market share at their expense. *So what has to be done?*

- 1. Research:** Make Austria a major player in Real-Time (RT) CPS/IoT, by building on its national strengths. TTTech is a worldwide leader in RT-connectivity, Infineon and ams in sensors/actuators, and Grassfish in their use. We will collaborate with these and other Austrian companies, to create an RT CPS/IoT-Ecosystem, where we can all experiment with new ideas, and develop this way an Austrian know-how. This effort will be aligned with the strategic Austrian initiatives, Industry 4.0 and Silicon-Austria.
- 2. Education:** Prepare next-generation Austrian work force, by using this Ecosystem, in courses where students learn/deploy novel CPS/IoT concepts related to connectivity, monitoring, prediction and optimization. This project will create a prototype in Vienna, by connecting TUW, AIT, and IST. A next project will deploy a similar infrastructure at JKU, KFU, AAU, and US. Our ecosystem will take advantage of our own buildings and offices, and of the Center for Digital Production (CDP) established at TUW.

Planning: 1) *Design* an RT fog/cloud connecting the offices of TUW, AIT and IST. 2) *Buy* thousands of sensors/actuators as well as gateways/switches from Austrian companies. 3) *Build* the associated RT fog/cloud by involving undergraduate/graduate students. 4) *Apply* this experience to the CDP. 5) *During this time*, both our students and the companies we will work with will accumulate a considerable know-how in CPS/IoT connectivity and monitoring. 6) *Add prediction and optimization* capabilities to get a full CPS/IoT picture. 7) *Pass/improve* this know-how through new courses and research/industrial cooperation.

Responsibilities: 1) *TTTech and TUW* will be responsible for connectivity, monitoring, and optimization; 2) *IST* for prediction, and 3) *AIT* for security.

Governance: The CPS/IoT-Ecosystem is a living-lab that will be integrated in the research and teaching activities of the TUW. As a consequence, the faculty of informatics will primarily support its maintenance through the annual budgets allocated to its laboratories, and the technicians of the institutes involved in this project. The CDP CPS/IoT infrastructure will extend this scope, with the mechanical engineering, electrical engineering and architecture faculties involved in this center. Through Silicon-Austria, the Ecosystem may be developed further, to better suit the Austrian needs. Moreover, we plan to extend this Ecosystem through the participation of the other Austrian universities. The local governance, will be ensured by a board, consisting of the TUW, AIT, IST and TTTech PIs, whose leadership is going to be assumed by Prof. Grosu, the lead PI.

Risk analysis: The main risk is to failing to recruit the necessary undergraduate/graduate student support for building the Ecosystem. However, this risk may be mitigated, by the aggressive advertisement of exiting projects, and bachelor/master/PhD thesis.

Sustainability: The CPS/IoT-Ecosystem corresponds to the strategic planning of the faculty of informatics, of the TUW and of the Austrian ministry, as it supports research and education in areas such as CPS, Industry 4.0, Smart City, Smart Mobility and Smart Health.

Quality assurance: The quality of the CPS/IoT-Ecosystem research and teaching activities will be monitored by an Advisory Board, consisting of leading personalities from both academia and industry: Edward Lee (UC Berkeley), George Pappas (UPenn), Manfred Broy (TU München), Doron Peled (Bar Ilan), Johann Massoner (Infineon), Michael Paulweber (AVL), Ernst Haselsteiner (ams) and Roland Grassberger (Grassfish).

Utilization Concept

Austria will become a major player within the CPS/IoT revolution only if it synergistically combines its own industrial and academic strengths. The CPS/IoT-Ecosystem can be seen in this respect as a vehicle for creating such synergies. These will:

- 1. Increase visibility:** The CPS/IoT Ecosystem will be a key Austrian infrastructure, ensuring the success of national (e.g. FFG, FWF) and European (e.g. H2020, Artemis, ERC, FET) proposals, investigating the most relevant scientific and technological topics of the CPS/IoT Revolution: Connectivity, monitoring, prediction, optimization, safety, security, robustness, autonomy, adaptivity, etc.

We plan to provide a free access to our (sensing) data through explicit cooperation projects only. This will incentivize the Austrian companies to work with us and will thus establish a cooperation platform for the entire Austrian industry. We also plan to use the similar scheme for academia. Interested academic partners should suggest a cooperation project that we will review. This way both sides will have an incentive for working together and this will strengthen cooperation among Austrian academia.

- 2. Strengthen connectivity/monitoring providers:** The CPS/IoT-Ecosystem will be a key infrastructure, allowing Austrian connectivity and monitoring providers to experiment with new ideas, beyond the scope of their immediate business.

Working together to build a CPS/IoT-Ecosystem, with real-time (RT) guarantees, will provide the necessary motivation for the Austrian connectivity providers, such as TTTech, to deal with thousands of sensors/actuators, and to construct RT-Fog and RT-Cloud solutions. These are beyond their state-of-the-art, and working on such topics is expected to lead to many innovations. Sensor/actuator providers, such as ams and Infineon, need demonstration toolkits and applications, in order to sell their products. Our Ecosystem will be a fantastic test-bed where they can rapidly deploy their innovative chips, and create sales demos for their solutions. The know-how can be passed thereafter (through cooperation projects) to further Austrian companies.

- 3. Strengthen prediction/optimization providers:** The CPS/IoT-Ecosystem will be a key infrastructure for users of connectivity and monitoring, for the purpose of prediction and optimization. Such users will include both large companies (e.g. in manufacturing, transportation, utilities, environment) and especially small and medium companies (SME) such as Grassfish.

Our ecosystem will allow SME who lack the necessary infrastructure, to use our own infrastructure within cooperation projects, to experimenting with daring new solutions. The know-how accumulated can be than passed through cooperation projects to additional SME. Investigating prediction and optimization in manufacturing will be facilitated by our CDP-Fabrik, once we have established connectivity and monitoring.

- 4. Build next-generation workforce:** In order to enable and sustain the CPS/IoT-Revolution we need to prepare the next-generation Austrian work force.

We plan to use the CPS/IoT-Ecosystem in courses where students learn/deploy novel CPS/IoT concepts related to connectivity, monitoring, prediction and optimization. The beneficiaries of this project will be in the first place the students of TUW, AIT, and IST. However, we plan to allow the use of our infrastructure in classes taught at JKU, KFU, AAU, and US, after getting our explicit permission. We also plan to pass our know-how to these universities, by helping them to build their own infrastructure, and linking it to our own. This will lead to a truly national CPS/IoT-Ecosystem.