Virtualization for Manufacturing and IoT

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Integrated Industry brings even more information technology and software to the shop floor. Virtualization offers numerous economic and technical benefits and therefore has been a standard in server farms and the cloud for over a decade. On the other hand, virtual machines add significant overhead which has so far precluded it from making serious inroads in embedded systems common to production environments. In a new development, Linux Containers now offer a Virtualization method that can be used on small computers and embedded systems. Contrary to full virtual machines, containers do not emulate hardware and share a single kernel with the base system using standard Linux technologies. Nevertheless, containers sandbox and encapsulate applications. This way every application and even every sensor or actor can be virtualised in a container and given its own IP address.

Virtualization

Virtualization is an accepted part for server and cloud infrastructure. It offers many technical and economic advantages including:

- Minimising the number of servers that have to be purchased and maintained.
- Easy scalability
- Straightforward sharing of resources
- Systems and applications can be sandboxed which provides additional reliability and security

In most cases, virtualization was achieved by virtualizing entire operating systems (see Fig. 1) by running a hypervisor on a base OS to manage the individual virtual machines. Every virtual machine contains a complete operating system which is then used to run individual applications.

This approach has some downsides, including:

- Every virtual machine contains an operating system which has to be managed, patched, and serviced.
- Large CPU overhead and memory use by the operating systems.

These disadvantages have so far precluded the wide adoption of virtualization in embedded systems.

IoT – Integrated Industry

The goal of Integrated Industry is merging the IT World and manufacturing. So far, virtualization wasn’t a consideration in manufacturing, though. The Internet of Things and Integrated Industry are now introducing more and more software into manufacturing environments. It would be natural to introduce virtualization to small computers and embedded devices to achieve the same benefits as in other IT systems like simplified management, more effective use of hardware resources, and improved security through sandboxing to manufacturing systems. Unfortunately, the overhead added by classical virtualization is unacceptable on the type of embedded systems used in manufacturing and machine environments.
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Lightweight Virtualization Using Linux Containers

Linux Containers (LXC) do not use virtual machines, but using so called containers. Rather than a complete operating system, each container only contains what is needed to run the specific virtual environment: code, runtime engines, libraries, system tools, and applications. All containers share a single kernel—albeit in separate protected memory spaces. (Fig. 2).

At the most basic level, a container is simply a file system containing the application and the libraries and files needed to run it.

Virtualization in manufacturing environments

HARTING IIC MICA (Modular Industry Computing Architecture) is the first system offering usable virtualization on embedded devices for manufacturing use. (Fig. 3). Using Linux Containers on top of a streamlined base OS, it is capable of virtualizing field devices without the overhead of conventional virtualization.

Containers sandbox and isolate an application from the operating system without the disadvantages of classic virtualization. Containers do not have a hardware emulation layer, but own their own processes. The processes run in separate kernel namespaces. Cgroups manage resources, so each container can be assigned necessary resources. In effect, the container architecture provides an extended chroot environment similar to BSD-jails and Linux VServer. But in a much more easy-to-use way than chroot and at the same time much more streamlined than a full virtual machine.

This minimal virtualization lets containers start up almost instantly and keeps processing speeds close to “bare-metal”.

The fundamental technologies for containers have been around for a few years, but have been complicated and hard-to-use for the longest time. But starting in 2013 proliferation of cloud technology and the following exponential growth in the number of virtual machines has shifted containers into the mainstream of IT and significantly improved their usability.

Fig. 2: Lightweight virtualization using LXC containers.

Fig. 3: MICA – Virtualization on a compact device.
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RAMI 4.0 – Integrated Industry Layers on MICA

The Reference Architectural Model Industry 4.0 (RAMI 4.0), developed jointly by the German standard bodies ZVEI and VDE, consists of a three-dimensional coordinate system that describes all crucial aspects of Integrated Industry. In this way, complex interrelations can be broken down into smaller and simpler clusters.

The six layers on the vertical axis serve to describe the decomposition of a machine into its properties structured layer by layer, i.e. the virtual mapping of a machine. Such representations originate from information and communication technology, where properties of complex systems are commonly broken down into layers.

A simple pump, a sensor, or a linear motor is usually not capable of talking to IT systems or each other. By using bar codes, RFID, or other means of identification it is possible, though, to assign them a unique ID and a virtual representation. This virtual instance contains all the relevant properties and capabilities of the device.

MICAs containers offer a natural way to encapsulate each instance and RAMI layer in a container. This means that every instance and layer has a unique IP address making it trivial to access them in a way consistent with the principles of IoT or Integrated Industry. To put it another way, any sensor or actor connected to MICA can be readily identified and accessed through and IP network—no matter how old it is, or which protocols it supports.

Retrofitting IoT to Legacy Systems

This means that, for example, even sensors only supporting a pre-IT protocol like S0 or simply analogue voltages can be virtualized in a container and then accessed over the network by using the container’s IP address.

In more complex scenarios, MICA can combine and aggregate data coming from multiple sources or orchestrate PLCs or similar devices. For example, it could read data of a PLC in the PLC’s native data format, convert the data, and then send it to an ERP gateway like SAP Mii using OPC UA. Conversely, it can download workflows from the ERP as JSON objects, translate them into PLC programs, then pass these on to a PLC and then instruct the PLC to run the program.

This approach lets users integrate legacy systems into MES systems, ERP systems, or the cloud quickly and easily.