THE INTERNET OF THINGS AND CONTROL SYSTEM

Vincent Hardion, Darren Paul Spruce, Antonio Milan Otero, Julio Lidon-Simon, Mirjam Lindberg, Andreas Persson, MAXIV Laboratory, Lund, Sweden

Abstract

A recent huge interest in Machine to Machine communication is known as the Internet Of Things (IOT), to allow the possibility for autonomous devices to use Internet for exchanging the data.

The Internet and the World Wide Web have caused a revolution in communication between the people. They were born from the need to exchange scientific information between institutes. Several universities have predicted that IOT will have a similar impact and now, industry is gearing up for it.

The issues under discussion for IOT , such as protocols, representations and resources are similar to human communication and are currently being tested by different institutes and companies, including start-ups. Already, the term smart city is used to describe uses of IOT, such as smart parking, traffic congestion and waste management.In the domain of Control Systems for big research facilities, a lot of knowledge has already been acquired for building the connections between thousands of devices, more and more of which are provided with a TCP/IP connection. This paper investigates the possible convergence between Control Systems and IOT.

INTRODUCTION

The Internet of Things[1] is seen as the natural evolution of Internet including not only the communication between human but also with any kind of object. This article is an introduction to the Internet Of Things. An analysis of the convergence of this domain and the Control System is presented at the end.

INTERNET OF THINGS

From Internet to Internet of Things

Who could predict the success of Internet 30 years ago? Nowadays, the Internet is used to communicate by more than 2 billion people[2] per day. When Tim Berners-Lee created ENQUIRED, the ancestor of WWW, he just wanted his articles to be better organised. It took 9 years to develop the WWW protocol[3]. Now its deployment so huge that the people are often confused with the Internet itself. Its improvement on the communication are so important:

- Fast access to information: it is so inexpensive and fast to publish information and the reader only needs to open a browser to see it. The circulation of events is made easier by the social network (i.e arab spring)
- Information as a Service : Unlike traditional media there is no waiting time to get to the interesting information. So, people browse the Internet instead of watching it. This is facilitated by the search engine which allows faster location of information.
- Memory, a very large library : the information are transmitted, copied all around the network.
- Hyperlink: accelerate the connexion to the related information.

The ability to transmit data between heterogenous computer networks has been made possible by the invention of the Internet. A huge amount of de-facto standard protocols and services are issued from the Internet, such as TCP/IP, mail, file transfer, remote connexions and HTTP, the most popular.

The Internet Of Things is born with the idea to reproduce this idea of human interconnection but for the machine.

Things

Nowadays, the computer is not the only way for people to access Internet. Autonomous devices like smart phones and tablets embed enough CPU power to become the standard client. Their introduction had a large impact on the way to represent information and they have generated new paradigms of use, like the push event. Other varieties of devices also exist, such as the Tux Droid[4] which are directly connected to Internet, without a screen and can process data.

The Internet Of Things goes beyond the human to human communication allowing the devices to communicate together without human interaction.

Sensor and Actuator

The “Sensor” or “Actuator” is often used to describe the things that could be connected to the physical world.

Sensors play a major role to generate information processed from the physical world. Traditionally several domains already use sensors but a processing unit (computer) is needed to access their information from a computer network, usually located on a local network. The sensors defined by the Internet Of Things are directly connected together to a global network with Internet, similar to computers. This idea came with the apparition of new technologies based on RFID[5] giving a communication skill to the passive objects. A major issue to resolve is privacy since the device does not have the same sensitivity as humans to control the circulation of data.

An actuator is a device which can act on the physical world. The IP bulb is one example of this category. They are often only connected to an Intranet as security is a critical constraint.

Applications

Today the Internet Of Things has become a reality in several applications[6], among them :

- Smart Cities: waste management, urban planning and environment[7].

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- Health: Ageing population, continuous care, emergency response[8].
- Commercial: smart product management
- Agriculture: Smart farm is using wireless sensor on cattle to know when one is sick or pregnant[9].
- Energy and Environment: FRED[10] is a sensor network to monitor the energy management of countries and states all around the world. In the same way, "Our Planetary Skin"[11] project is a sustainable water management platform.

CONTROL SYSTEM, AN INTRANET OF THINGS

"All of the Internet has been built by human processed data : web pages, blog, social network. The problem is, people have limited time, attention and accuracy—all of which means they are not very good at capturing data about things in the real world" [1].

The primary reason of the existence of the control system is to ensure the capture all of the important data from a thousand of devices necessary to operate a big scientific facility.

The field bus or secondary control system and the primary control system traditionally form the architecture of the whole control system. The controllers which are situated close to the equipment represent the main elements of the field bus allowing the control of passive devices. The operators and the controllers are interconnected through the primary network.

Since the wave of industrial programmable logic controllers (PLC), the distributive aspect of control systems has improved a lot. Nowadays, field busses are more heterogeneous. On the other hand the flood of Internet hardware has often pushed the primary network to be based on the common TCP/IP stack. Only using ethernet has dramatically decreased the price of each connection by letting the field bus managing the hard real time task. Out of all the devices controlling the MAX IV linac, 28% are controlled with a PLC and 43 % are controlled with specific controllers using TCP/IP over ethernet. These include power supplies and ion pumps. Ethernet control is possible because these devices include an embedded controller with a microprocessor also with ethernet capabilities. The communication protocol with the control system is often achieved through a tcp/ip socket in a plain text protocol like SPI, or with a binary protocol issued from Internet like CORBA, eventually with the same protocol as the main control system (EPICS, Tango, ...).

The last generation design of software frameworks for control systems used by scientific facilities is also an outcome of the Internet revolution. These frameworks interconnect all devices on the primary network with the client applications. In fact, the primary control systems of scientific facilities are primarily tailored for the Machine to Human communication (monitoring sensors) representing mainly the data in a SCADA, or for Human to Machine action (steering actuators). But the development of virtual controllers with a primary Machine to Machine communication is more and more common. Actually, any application which only needs "soft real time" can be developed in the primary control system, like the slow orbit feedback for a synchrotron. In some control system frameworks, the controllers are fully abstracted to represent only the functional object. For example Tango and DOOCS follows the object oriented programming paradigm. For Tango the term "Device" is equivalent of Things, encapsulating state, command, attribute value, unit, threshold. In conclusion, a Control System is an IOT in a confined network.

FAST ORBIT FEEDBACK SCENARIO

The correction of an electron beam in a ring is done with 2 possible functionalities:

- The Slow Orbit FeedBack (SOFB) is a correction of the electron beam orbit at 10Hz, achievable by software.
- The Fast Orbit FeedBack (FOFB) is a fast correction of the electron beam orbit at 10kHz.

The power supplies of the correction magnets play the role of the actuators. The sensors are the beam position monitors (BPM's). The scenario described below could also be applied in the beamline with the motors of a monochromator and an intensity monitor.

The MAX IV Laboratory will use ITest[12] power supply controllers to steer the correction magnets without embedded capability to natively communicate with Tango and the Instrumentation Technologies[13] Libera Brilliance plus (LB+), a BPM controller coming with 2 processing units:

- one low level with FPGA for the real time processing of 4 BPM
- one which embeds a Linux OS for the communication with the Tango Control System.

LB+ delivers various BPM parameters but it has enough computation power embedded to steer the actuators in a FOFB closed loop.

First Layer: Control System Protocol

This first layer represents the connection of the device with the main control system. It's integration is faster if the device uses the same protocol as the main control system, like the Libera Brilliance plus and Tango. This has the advantage to avoid the software development phase, still mandatory for the ITest power supply.

On this layer the devices still can not register themselves automatically to the different services of Tango. The identification of each device is still needed and has to be human readable following the location and the role inside the facility (via naming convention usually). In this case the Machine model could make the link with each device include a GPS[14] or Galileo[15] unit.

Recently, the steps needed to integrate the LB+ and ITest devices in to the MAX IV control system were :

- the development of the Tango software, only for the power supply
- the choice of a server to run the Tango device of the power supply
- the definition of the appropriate name

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- the configuration of the device and the registration to the different services like the archiving or the alarm systems for example.

Second Layer: Control System Service

In the second layer, the control system should be able to determine the role taken by a device and/or its different functionalities. For example, the Libera Tango device should declare itself as a "sensor" representing a "BPM" with the possibility of "Orbit FeedBack". Similarly for the ITest Tango device takes on 3 roles; an "actuator", a "magnet" and especially a "corrector magnet". This ability is necessary for the application level programs to scan the different elements offered by the control system. A FOFB or a scan system could automatically detect them and integrate them into the list of possible device to control.

In addition to devices being able to export behaviour according to their role, the ability to fully identify the piece of equipment attached to the controller will provide more accuracy. For example a power supply device could inform of it's link to the first corrector magnet of the second ring achromat. In this case the magnet or the BPM are very passive components without communication skills with the IT system. If an RFID-like solution was used, it could transform a passive component into an identifiable, communicating device through the addition of an inexpensive electronic chip.

The present control system design does not permit identification of the relationships between active and passive components or identify their roles without any human interaction.

Third Layer: Control System Semantic

Once the devices are connected and their positions and their roles identified, the Orbit Feedback application running on the MAXIV's BPM controller has to be configured with the correct actuators, the sensors being already part of the BPM. In the IOT type scenario, the SOFB can detect the correctors located next to the BPM thanks to their current positions and it has the knowledge of what is an electron accelerator. Actually the MAXIV model will be also downloaded from another service to check if there is no specificity (i.e X and Y, the name of the reference axis can be different between the facilities).

On the other hand the FOFB operates with the fast correctors on hard real time. The system will check if the connection to the correct power supplies is done on the field bus. Here the field bus is like the primary control system and has to provide some high level service, such as the identification of the peers.

Maybe one day your BPM will ask you to try the new algorithm published recently but today to use a orbit feedback correction we have to:

- develop the SOFB and FOFB software
- identify the correctors and the BPM
- configure the algorithm
- run the correction

CONVERGENCE AND CHALLENGE

Behaviour and semantics are part of the convergence of IOT as well as the next generation of control systems in addition to the standardisation of the communication protocol and the data representation Both domains converge to reinforce the abstraction of the lower level hardware from the high level application. Clearly the trend is to embed a maximum of intelligence inside the device or 'things' themselves. To achieve this goal each have to define standard protocols, representations of the information and enough autonomy to behave by themselves.

Protocol

The Internet of Things means literally to connect everything. The issue to provide a huge amount of unique identity(UID) of each object has been resolved recently by the progressive move to IPv6 the protocol, given the possibility to connect 3.4×10^38 devices but only for TCP/IP based communication. Despite this, IOT doesn't yet define a standard protocol of transportation. Even the usual TCP/IP competes with the lowest protocols as they have the advantage to be less energy consuming.

In the Application layer [16] no standard has been taken but most of them are based on an event system (MQTT[17], XMPP[18]...). The enormous market potential doesn't help, resulting often in industrial companies pushing for their own technical 'standard' solution. However, some consortiums such as M2M[19] (Eclipse Foundation) or IOT-A[20] (EU) try to federate the standard and the tools.

Smart Things means that more intelligence will be embedded inside the device and one important key allowing the IOT is the possibility to connect itself to the network. Embedding the communication protocol inside the device implies that the Control System has to rely more on the primary network, letting the secondary to be more specialised for issues that need dedicated hardware (e.g. fast processing and timing of electronic signals). Gradually the specific COTS used for scientific applications has started to include protocols to communicate directly with the Control System such as the Libera units. These "CS plug and play" devices enhance their integration to the CS by defining their standard interface in a bottom-up way.

The Open Hardware[21] movement can lead to open the protocols with the same impact of Open Source on the current Web.

Ontology

Apart of the unanimous concept of Sensors and Actuators, the IOT stakeholders propose often a very specific solution for their domains of application.

In the control system area, some services are essential, such as the Archiving or the Alarm system. However, these are never usually compatible between different Control System frameworks. Also, the example given earlier in this article is one among several and only a study of the entire ontology for this domain can lead to a convergence (e.g. Acquisition in Sardana compatible with EPICS or Tango).

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Semantic

The need to identify information itself from an object is almost as important as the identification of each web page (URI). In this case the term Web of Things is often used for the possibility for machines to refer to each other. The Semantic Web[22] is one of the standard data formats proposed by the W3C to help machines access Internet knowledge (e.g. to recognise what is a synchrotron).

Artificial Intelligence

While semantics are a way to retrieve knowledge, Artificial Intelligence (AI) processes the information in a non-programmed manner.

Embedded computing power is necessary to bring high level applications to the device level. AI is mandatory for the autonomy in decision making and a guarantee for evolution, but as with the Internet, the challenge is to distinguish truth from falsehood.

At this stage the addition of AI to the device could lead the change of the "software developer" job to cybernetician[23].

CONCLUSION

It is not obvious that IOT will be a reality in 10 years following the constraints of energy and security. But now, this subject has engaged a lot of research and development[24] which will profit the control system domain in a similar way that internet has brought the benefits of TCP/IP and CORBA.

It is not obvious that an internet solution will be reused for the IOT even if this article highlights them. HTTP implementation may be too heavy[25] to be efficiently processed by low consumption devices.

The contribution of the control system domain to IOT is uncertain. The lack of federation caused by few requirements to have machine to machine communication between different facilities reduces the possibility of contribution to IOT. Maybe some initiative from the large facilities like CERN with the Open Hardware Licence[26] can contribute to an evolution of the embedded intelligence. On the other hand the recent discussion between MAXIV and ESS to share a common control room can lead to interconnect 2 different control systems, EPICS and Tango.

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