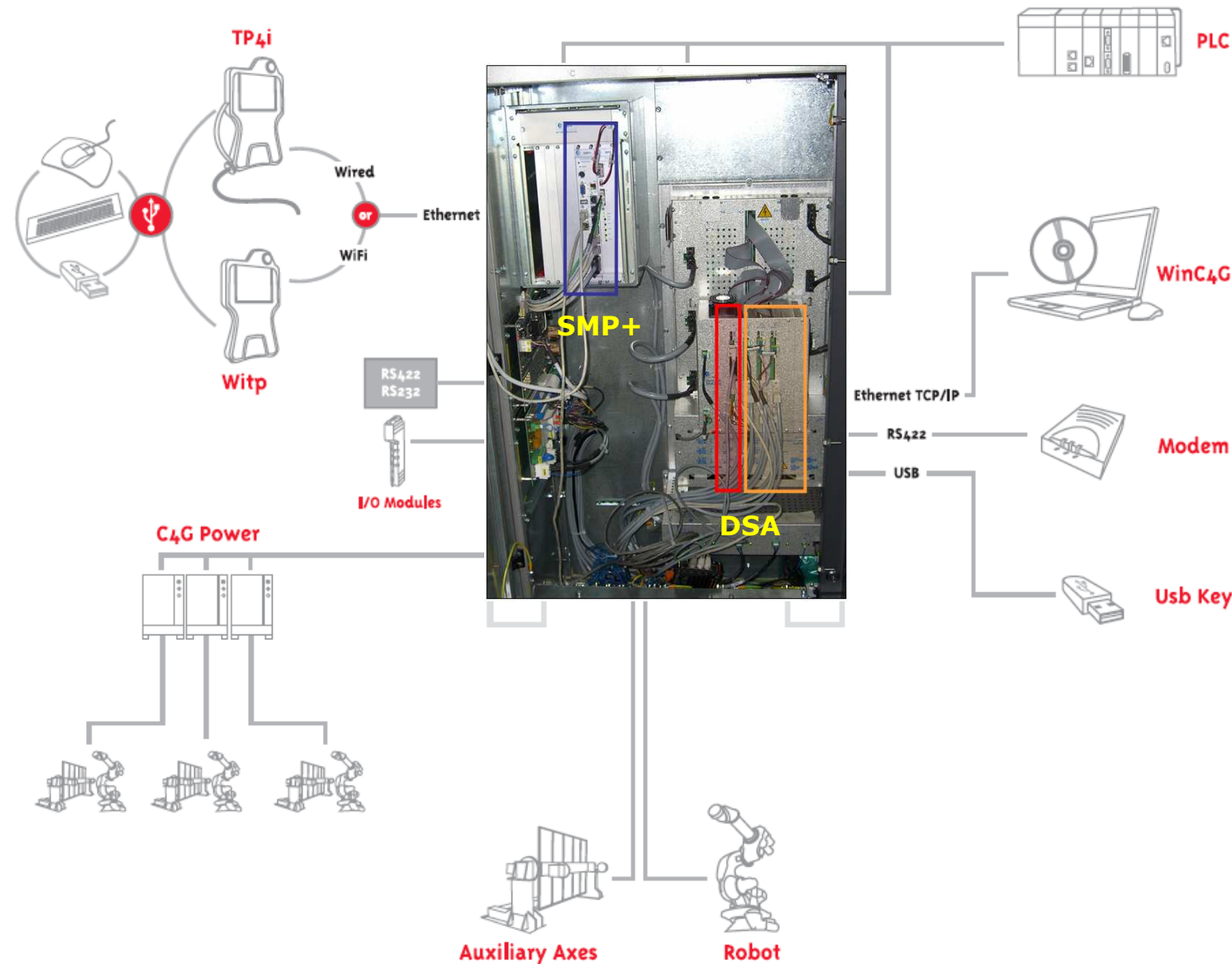


comau.com/robotics

The Open Source Controller in COMAU Robotics

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SMP+ (System Master Processor) board

- human machine interface management
- user programs interpreter
- trajectory generation
- dynamic model calculation
- axes inertia calculation
- payload identification
- collision detection
- joint soft servo
- high level adaptive control
- axes synchronization

MPC (Motorola Power PC) board

- trajectory fine interpolation
- position and velocity control loop
- low level adaptive control
- high level torque control
- master-slave management

DSP (Digital Signal Processor) boards

- current control loop
- power generation
- measurements

C4G Open is a technology developed by COMAU to simplify using robots in universities, in research centers and in SMEs

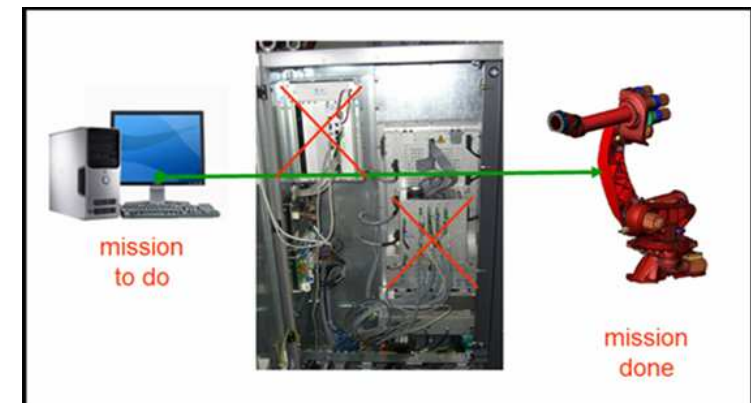
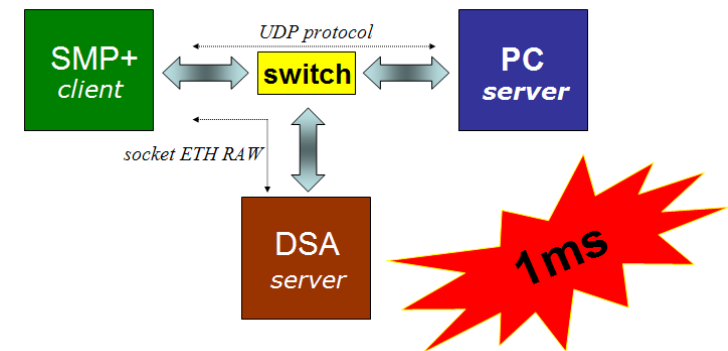
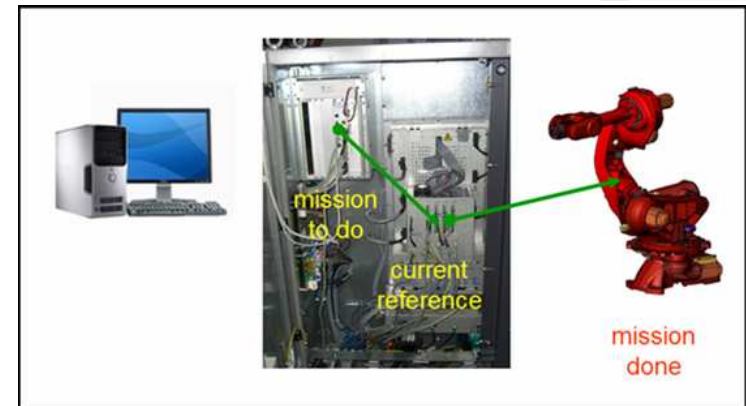
C4G: robustness and safety are guaranteed by classic supervising C4G systems

Open: an external PC can directly manage the robot using an Open Source communication protocol to generate the trajectory and/or to drive current references

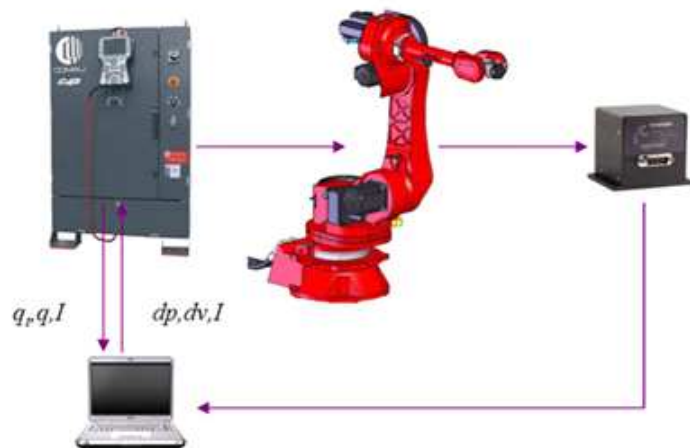
Powerful: a lot of operative modalities is supported, modality switching does not require robot stopping

Easy: PDL2 gives the possibility to use move instructions, system variables, signal and semaphores for concurrence programming, TCP/IP socket communications, I/O management

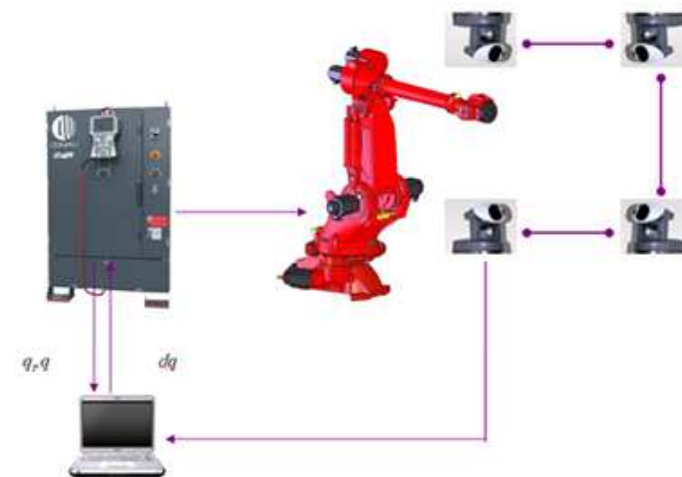
New: from the technologies implemented by industrial engineers to the methodologies studied by research people, the *rapid prototyping* approach



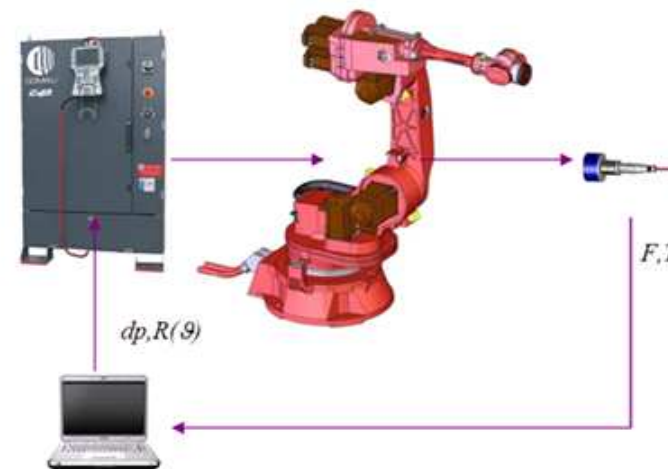
Applications with C4G Open



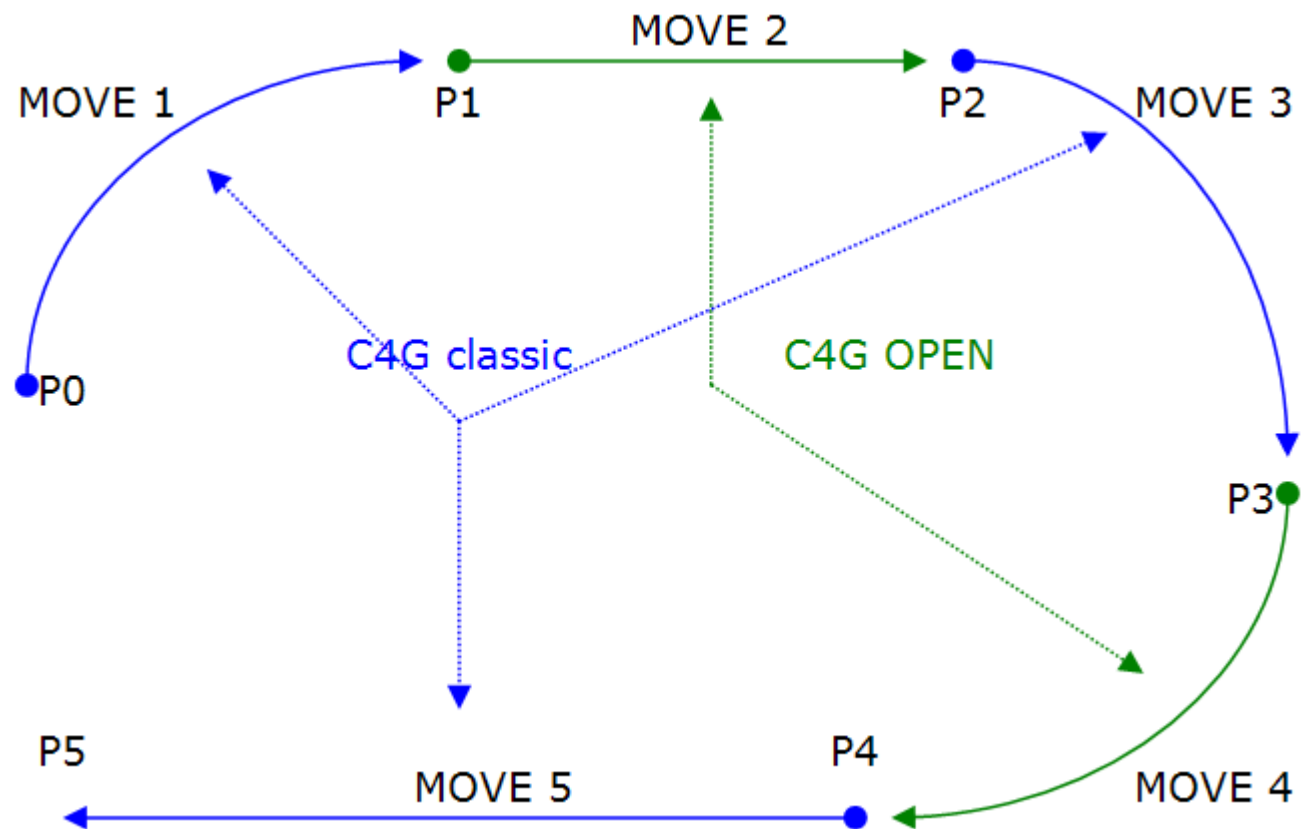
*control with integration of an IMU module
(inertial navigation)*



*control with integration of a vision system
(visual servoing)*



*control with force sensor
(impedance control)*



MOVE TO P1

GO OPEN TYPE A
WAIT PC

MOVE TO P3

GO OPEN TYPE B
MOVE TO P4
WAIT PC

MOVE TO P5



Operative mode switching does not require turning off the motors!

C4G Open Communication Packet

N°	Field type	SMP+	PC
NUM	LONG for packet	packet identifier	packet identifier
INFPAR	LONG for packet	information/commands	information/commands
SMax	LONG for axis	axis status	axis mode
D1ax	FLOAT for axis	target position [motor rounds]	target position [motor rounds]
D2ax	FLOAT for axis	target velocity [delta motor rounds]	target velocity [delta motor rounds]
D3ax	FLOAT for axis	measured position [motor rounds]	generic measurement [--]
D4ax	FLOAT for axis	estimated velocity [delta motor rounds]	velocity contribution [delta motor rounds]
D5ax	FLOAT for axis	current reference [Ampere]	current contribution [Ampere]
EXT1ax	FLOAT for axis	SMP+ first extra field	PC first extra field
EXT2ax	FLOAT for axis	SMP+ second extra field	PC second extra field
EXT3ax	FLOAT for axis	SMP+ third extra field	PC third extra field

packet



maximum number of ARM	4
maximum number of drives (DSA)	2
maximum number of axes	20
maximum number (for ARM) of axes	10
maximum number (for ARM) of auxiliary axes	4

restrictions

4	application		user program
3	function	basic functions	API
		FSM management	
		C4G Open packet management	
2	communication		driver
1	operative system		Linux + RT libraries
0	hardware		--

HW/SW Layer

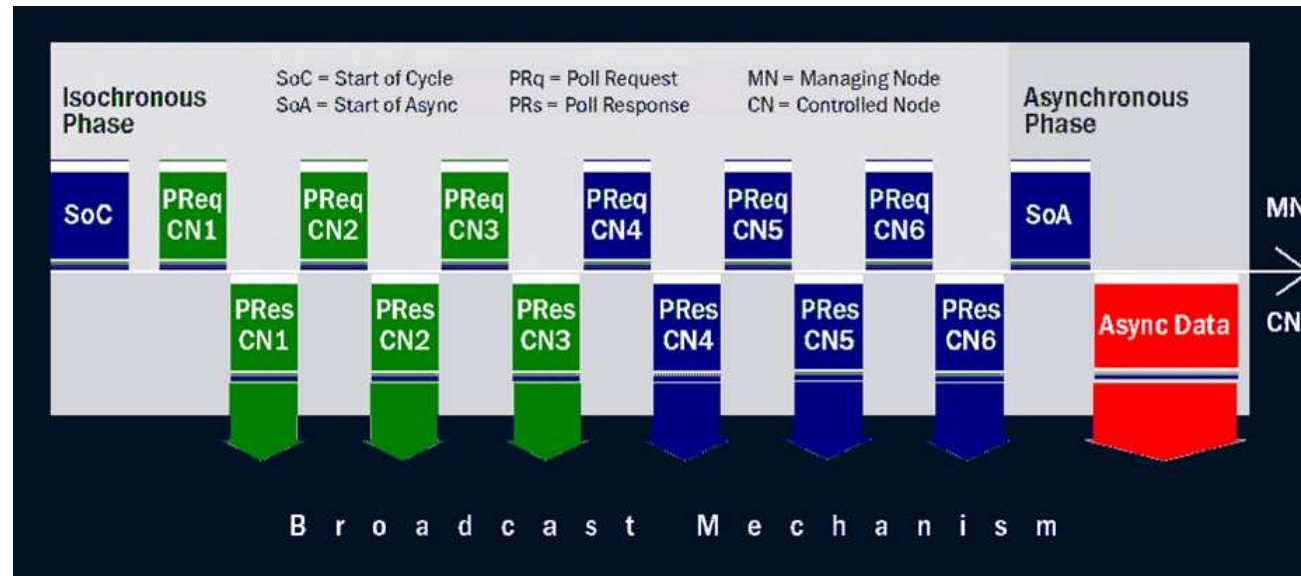
Ethernet POWERLINK (EPL) is a deterministic algorithm real-time protocol for standard Ethernet. It is an open protocol managed by the **Ethernet POWERLINK Standardization Group (EPSG)**.

Open Association: EPSG, the Ethernet POWERLINK Standardization Group is an independent registered association with a democratic charter. Founded by drive and automation industry leaders in 2003, the EPSG's members pursue their common goal of standardizing and enhancing POWERLINK technology.

Open Protocol: Released under the BSD license in 2008, the open source version openPOWERLINK is available free of charge. The EPSG does not levy any license fees for the technology. POWERLINK is an open technology.

Open Development: Various working groups within the EPSG engage in continual improvements to the technology in areas such as safety, technology design, certification, user requests, and marketing and sales.

Open Basis: POWERLINK technology is developed based on open standards like IEEE 802.3 (Standard Ethernet) and IEC 61784-2 (Real-time capable Ethernet-based field buses).



Start Phase: The **Managing Node (MN)**, is sending out a synchronization message (SoC - Start of Cycle) to all **Controlled Nodes (CN)**. This schedule design avoids collisions, which are usually present on Standard Ethernet, and ensures the determinism of the hard real-time communication.

Isochronous Phase: The Managing Node calls each node to transfer time-critical data for process or motion control by sending the Poll Request (PReq) frame. The addressed node answers with the Poll Response (PRes) frame. Since all other nodes are listening to all data during this phase, the communication system provides a producer-consumer relationship.

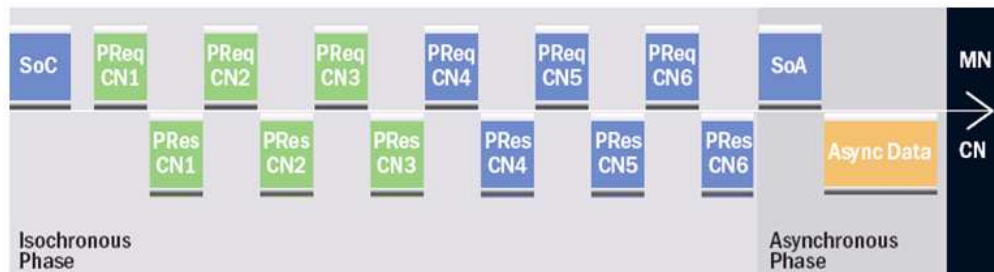
Asynchronous Phase: The Managing Node grants the right to one particular node for sending ad-hoc data by sending out the SoA - Start of Asynchronous - frame. The addressed node will answer with ASnd (the asynchronous data). Standard IP-based protocols and addressing can be used during this phase.

C5G Open looks at POWERLINK

Each **axis** moved by its **motor** is connected to a **drive** by the cables (power and measurement).

Each drive is associated to a **controlled node (CN)** on the POWERLINK network.

The **managing node (MN)** that is the arbiter and moderator of the “conversation” on the POWERLINK network is made by the main processor of COMAU controller (user programs interpreter, trajectory generation, dynamic model calculation).



The real-time information between MN and each controlled node CN are changing inside the isochronous phase of POWERLINK cycle time:

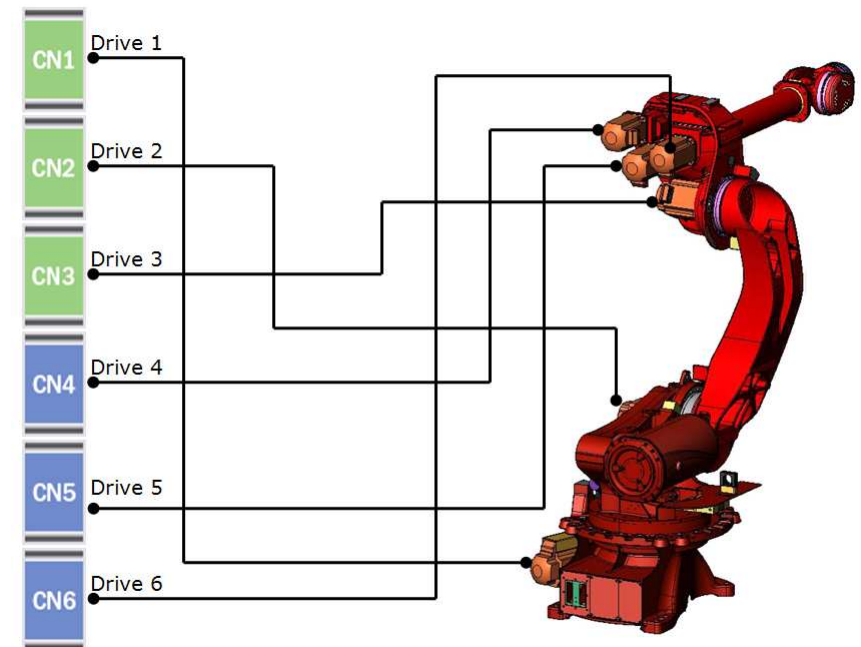
- from CN to MN*: measurement of the encoder position

- from CN to MN*: measurement of the torque current

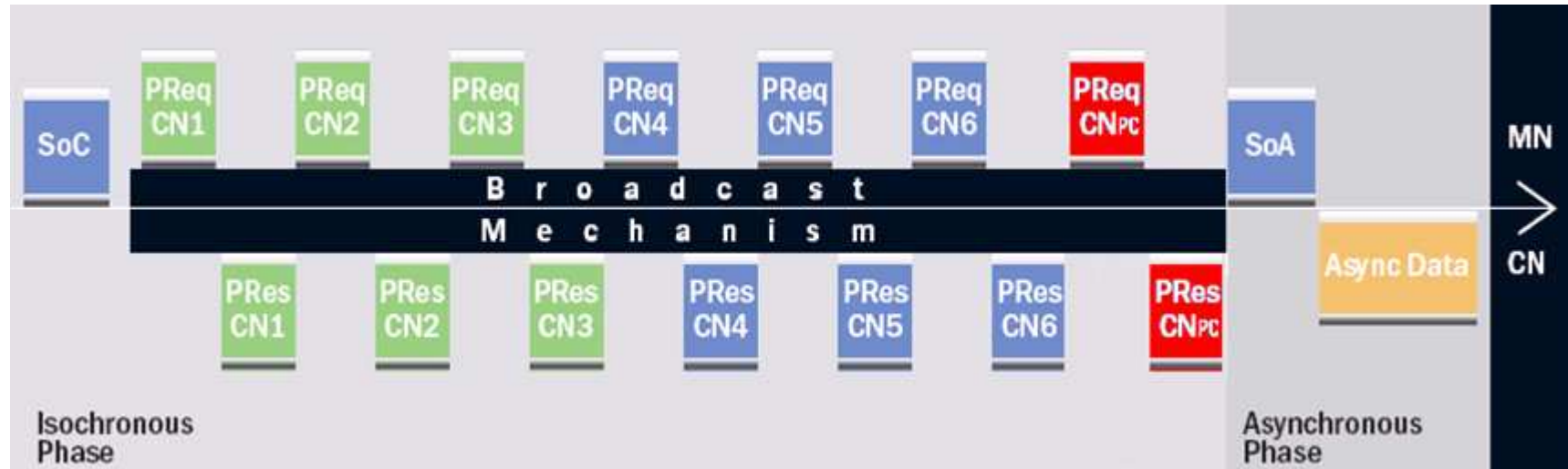
- from CN to MN*: other measurements

- from MN to CN*: current reference

The non real-time information (housekeeping operations) between MN and each controlled node CN are changing inside the asynchronous phase of POWERLINK cycle time.



C5G Open Architecture: easy and efficient

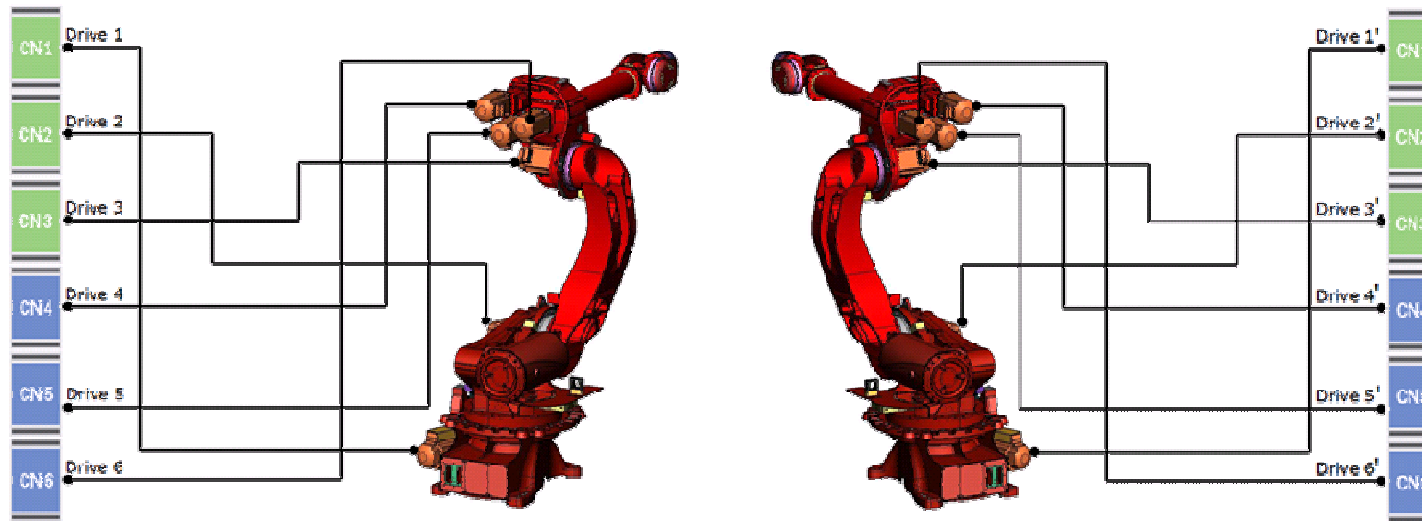


The Ethernet switch, present in C4G Open architecture, is not required because of the daisy chain connection between the nodes on the POWERLINK network. It's sufficient to buy an EPL standard cable and connect the latest node of POWERLINK to the network interface of external PC.

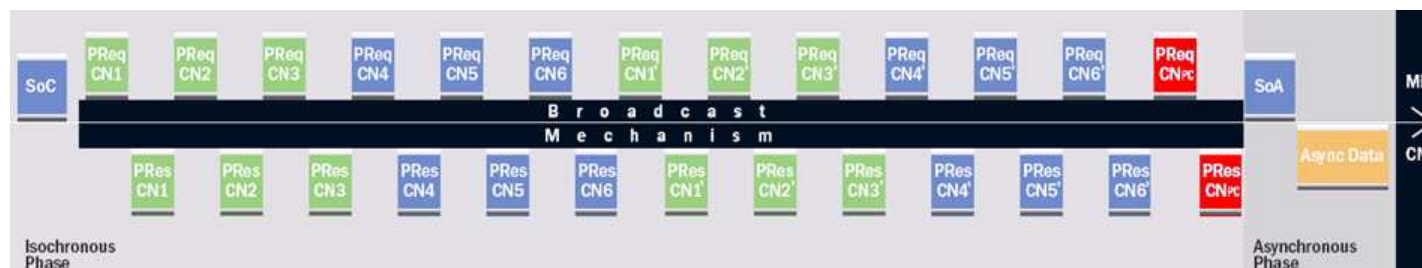
It disappears the role of "collector" of data made by C4G controller (all the information between the external PC and the drives passed through the communication manager) also.

In the C5G controller because of broadcasting concept of communication every node is free to broadcast its own data to every other node into the network. This permits to the CN_{PC}, the controlled node of the network card of the external PC, to receive all the information from the other controlled nodes and send to managed node MN all the references depending on the modality of open controller.

C5G Open Architecture: easy and efficient



- **1** COMAU C5G standard controller (of course with other 6 drives)
- **1** POWERLINK card for the external PC (the same EPL cable of the single ARM configuration)
- the controlled nodes CN_1 , CN_2 , CN_3 , CN_4 , CN_5 and CN_6 are related to the six drives that move the six motors of the first arm, the controlled nodes CN_1' , CN_2' , CN_3' , CN_4' , CN_5' and CN_6' are related to the six drives that move the six motors of the second arm
- the controlled node CN_{PC} is related to the network card of external PC
- the managed node MN is related to main processor of COMAU controller



COMAU C4G Open Controller is a very innovative control architecture that allows easy and safe integration of the industrial robot control and an external personal computer to enable external access to the robot control and interaction with it at several levels.

C4G Open Software is fully open source:

- the application layer is based on a ANSI C open communication packet and libraries distributed under the terms of GNU LGPL license
- the operative system is Linux 2.6.x with RTAI Real Time Application Interface and RTnet Real-Time networking stack extensions

COMAU C5G Open Controller joins the open capabilities of C4G Open Controller with the open source characteristics of openPOWERLINK protocol

OpenPOWERLINK, released under the BSD license in 2008, is the open source version of Ethernet POWERLINK (EPL) based on open standards like IEEE 802.3 (Standard Ethernet) and IEC 61784-2 (Real-time capable Ethernet-based field buses)

For these reasons C4G Open and, in the next future, C5G Open are a real examples of “Open architecture with Open source” for fast prototype research or production activities for industrial robotics companies.