



ESPE
UNIVERSIDAD DE LAS FUERZAS ARMADAS
INNOVACIÓN PARA LA EXCELENCIA

**VICERRECTORADO DE INVESTIGACIÓN, INNOVACIÓN Y TRANSFERENCIA TECNOLÓGICA
CENTRO DE ESTUDIOS DE POSGRADO
DEPARTAMENTO DE ELÉCTRICA Y ELECTRÓNICA**

MAESTRÍA EN ELECTRÓNICA Y AUTOMATIZACIÓN MENCIÓN REDES INDUSTRIALES

“IMPLEMENTACIÓN DE UNA ARQUITECTURA IIOT REDUNDANTE PARA EL MONITOREO EN TIEMPO REAL DE UN PROCESO DE PALETIZADO SIMULADO EN UN ENTORNO VIRTUAL 3D”

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Latacunga
2023

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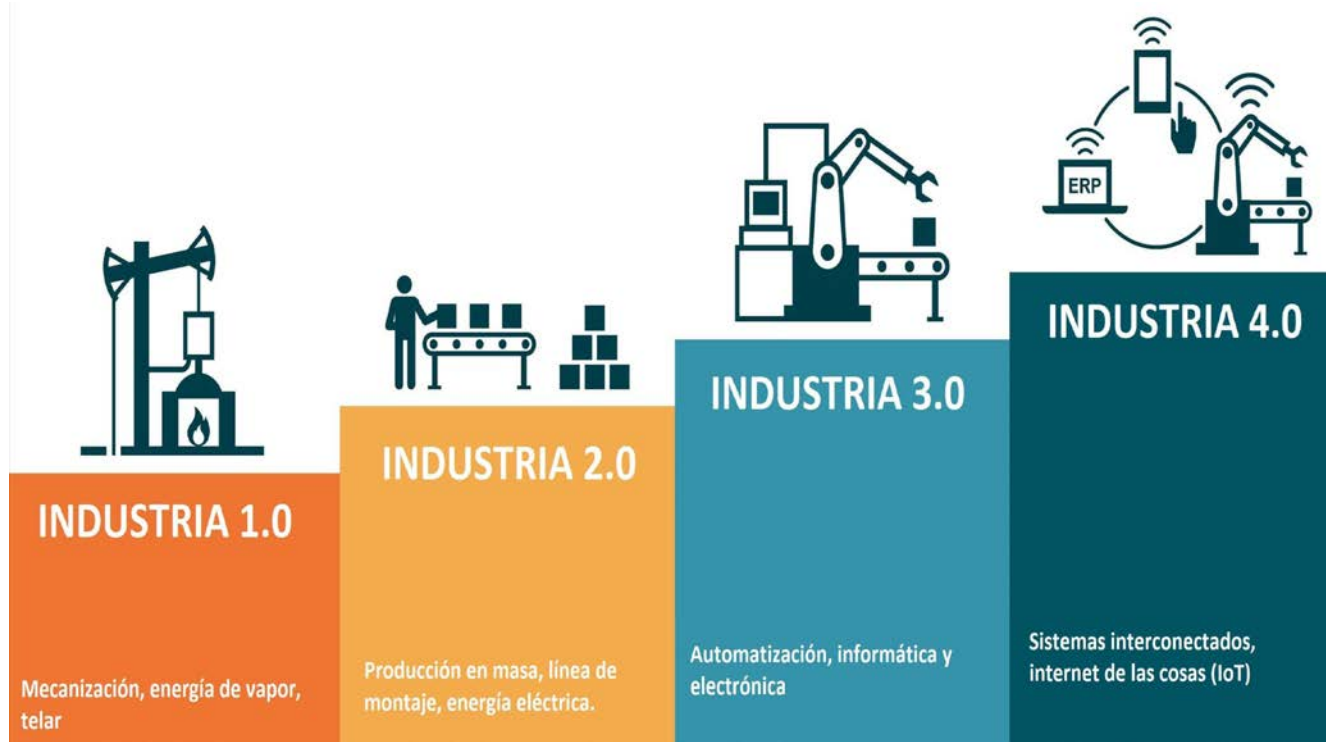
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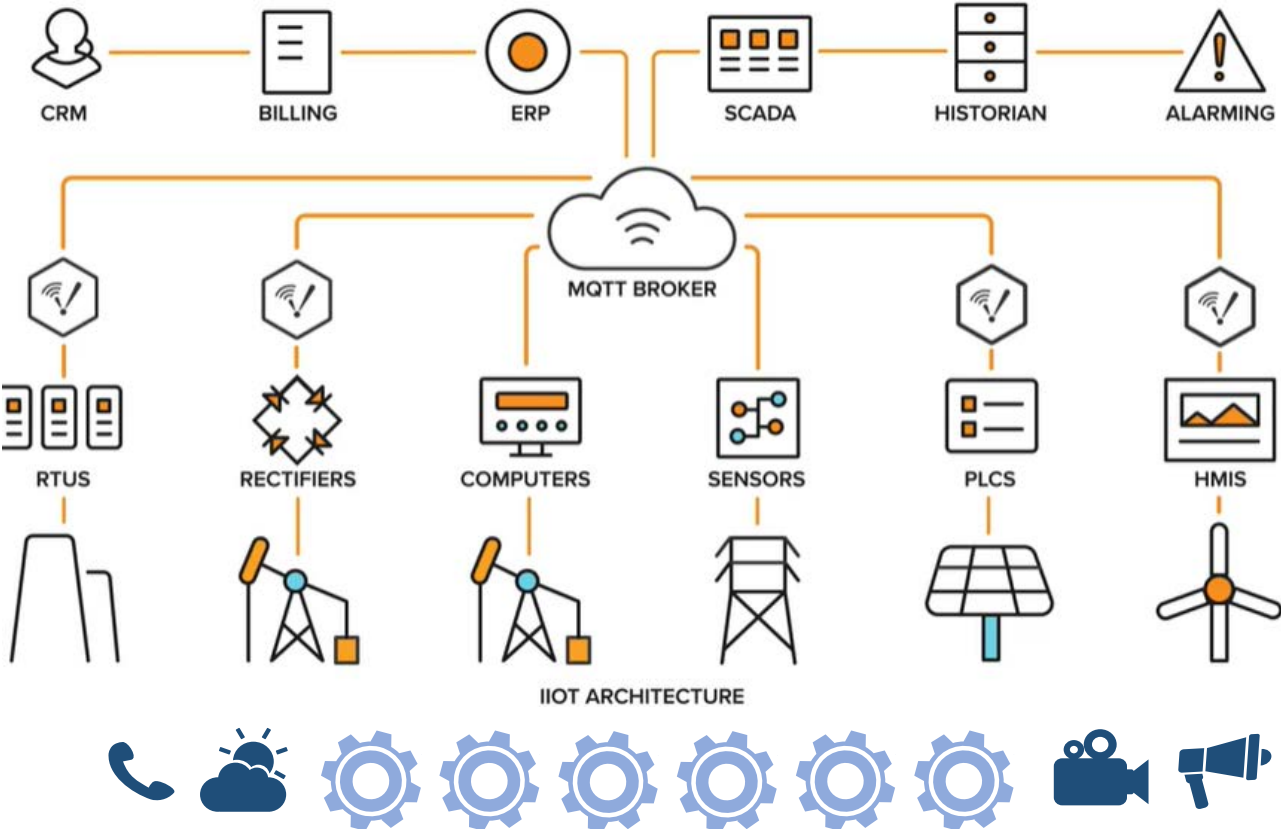
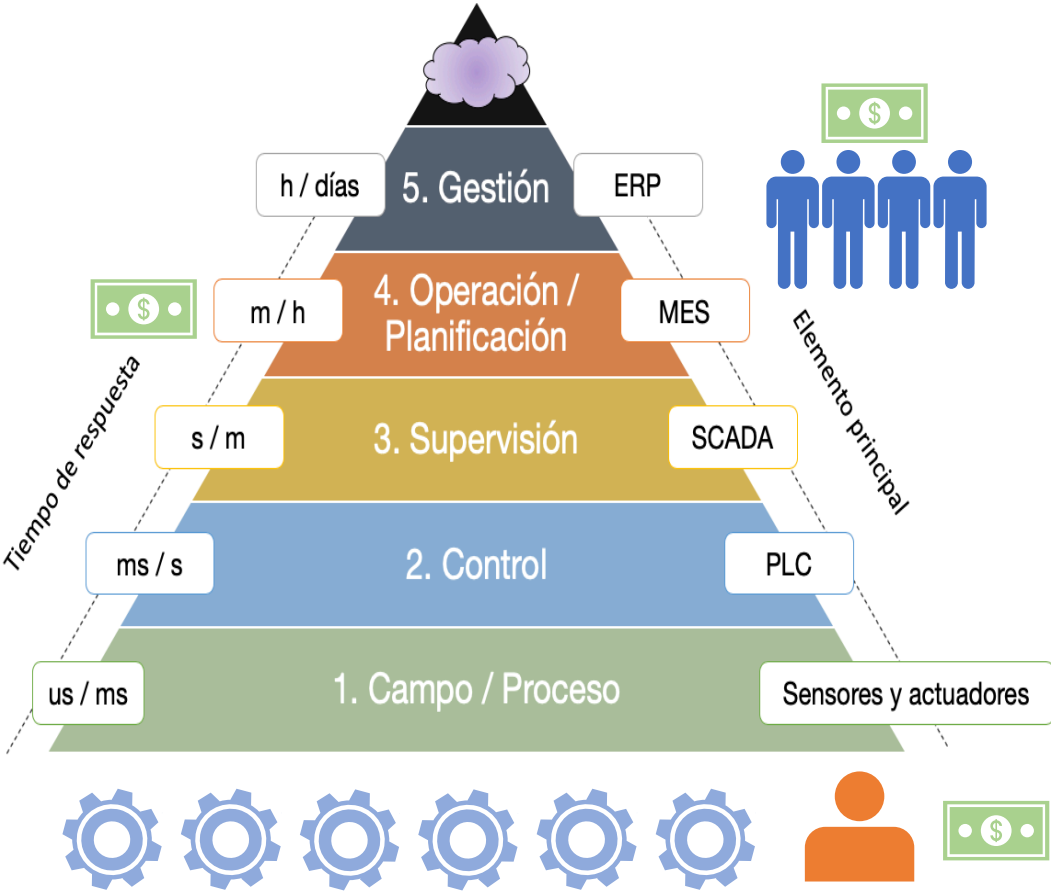
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Introducción

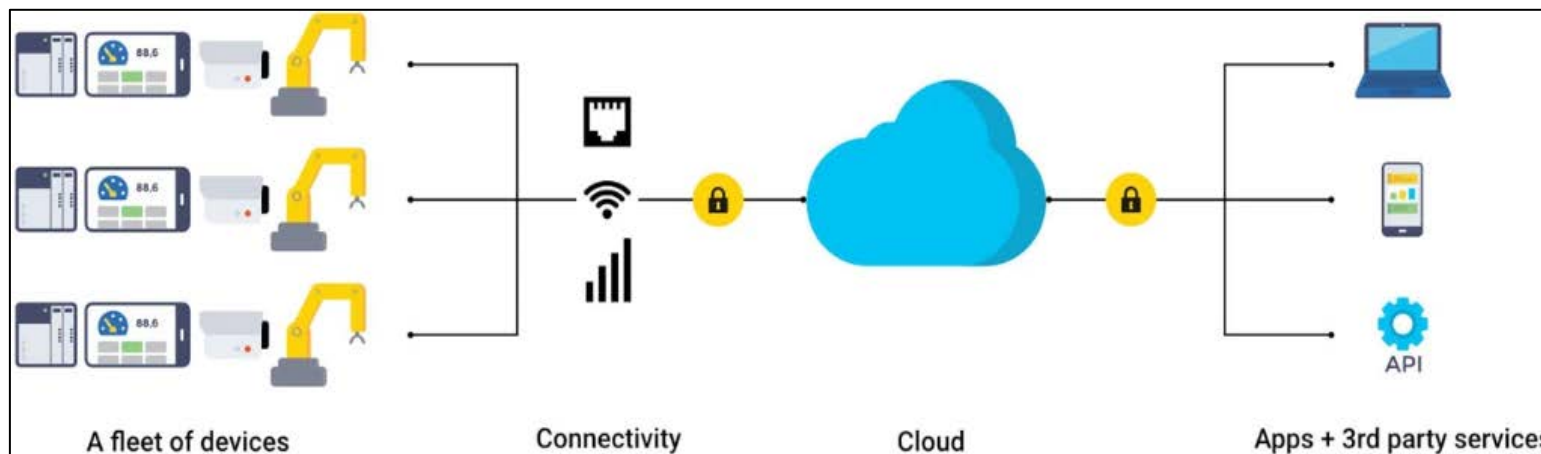
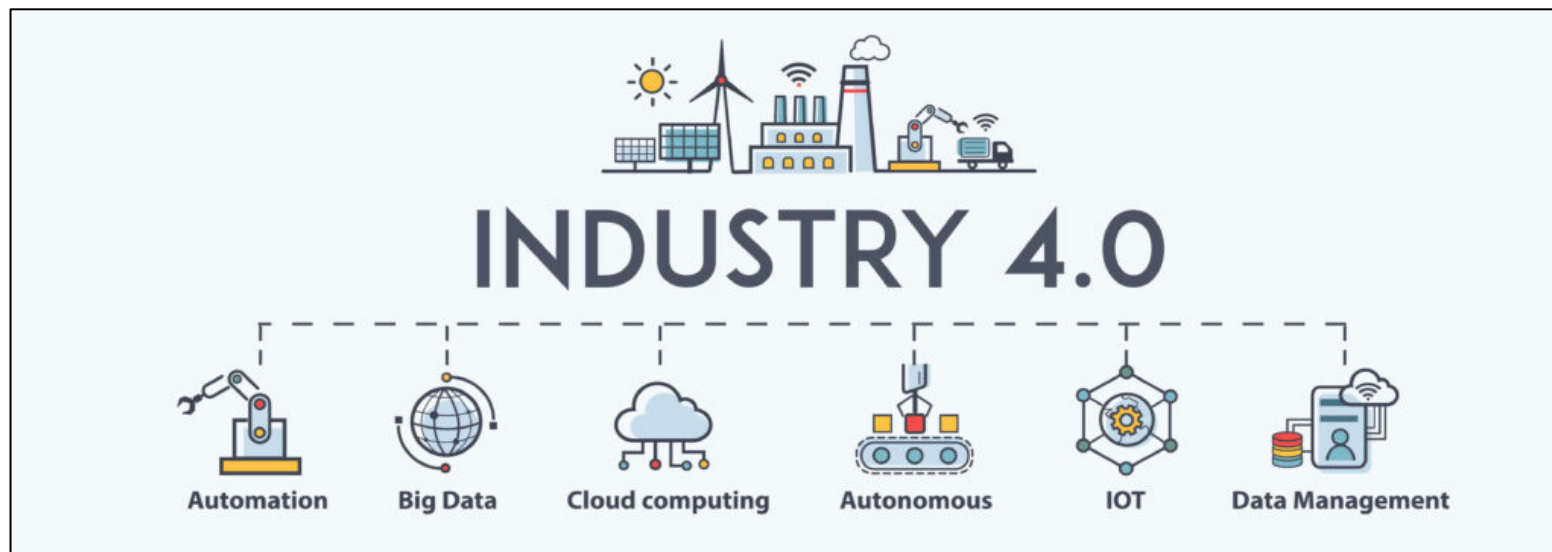


Antecedentes y Planteamiento del Problema



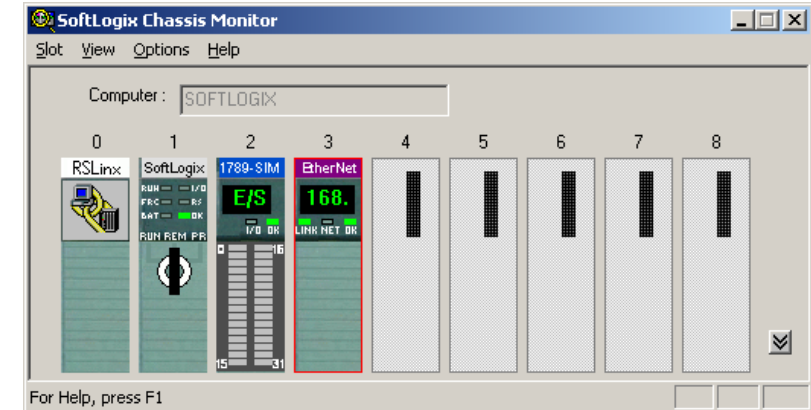
Justificación e Importancia

- Necesidad real de la industria.
- Competencia de Ingenieros en Automatización.
- Punto de partida de implementación IIoT.
- Probar tecnología sin equipos físicos.



Alcance

- Simulación 3D de proceso de paletizado.
- PLC que permita comunicarse con la herramienta 3D.
- Plataforma de automatización escalable, probada, de implementación sencilla.
- Arquitectura IIoT redundante, confiable, apta para procesos industriales.



SCADA

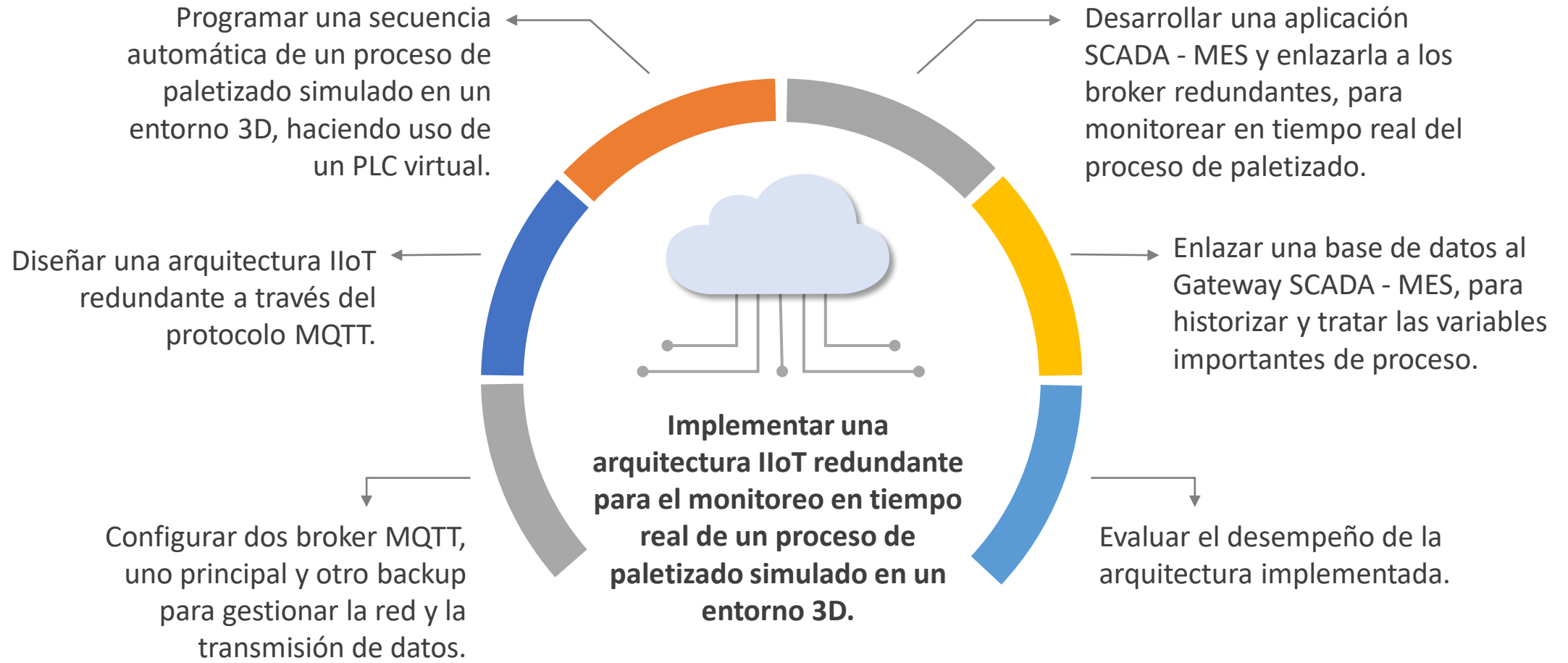
IIoT

MES

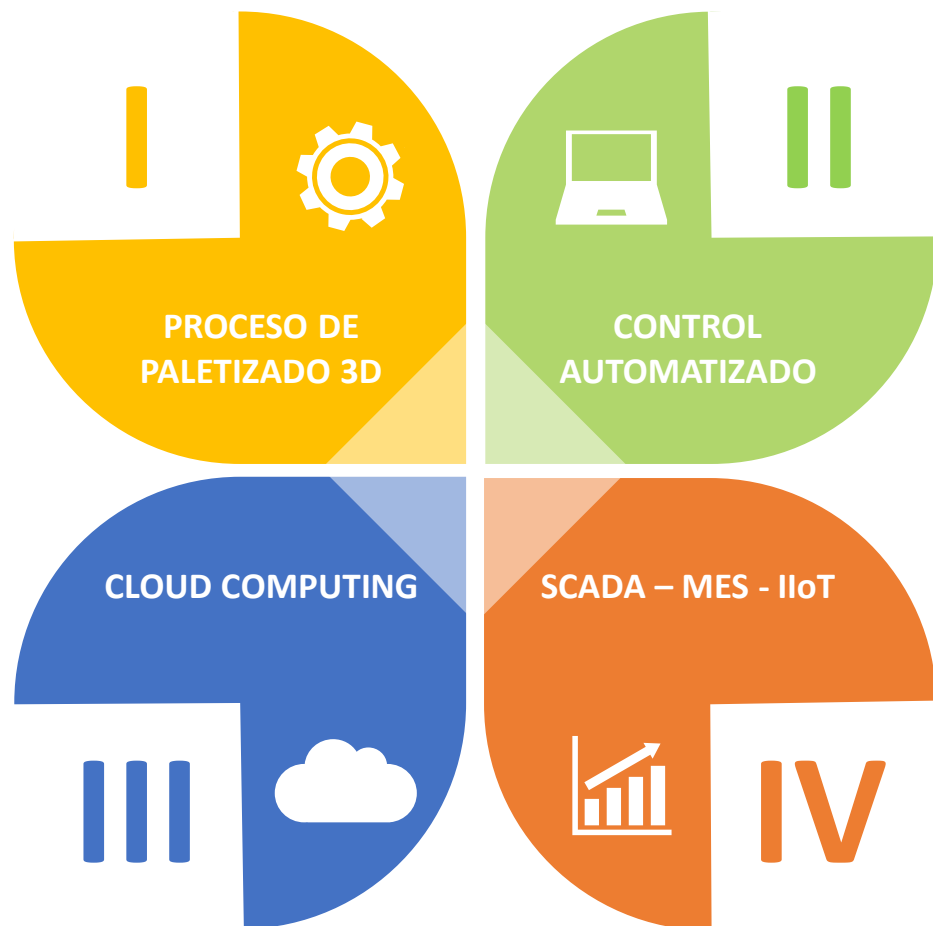


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Objetivos



Planteamiento de Solución al Problema



Factory IO

- ✓ Software de simulación de entornos industriales
- ✓ Módulos prediseñados configurables
- ✓ Múltiples protocolos para diversos fabricantes

Softlogix

- ✓ Simulación de PLCs de Rockwell Automation Logix 5000
- ✓ Ethernet - comunicación externa

Microsoft Azure

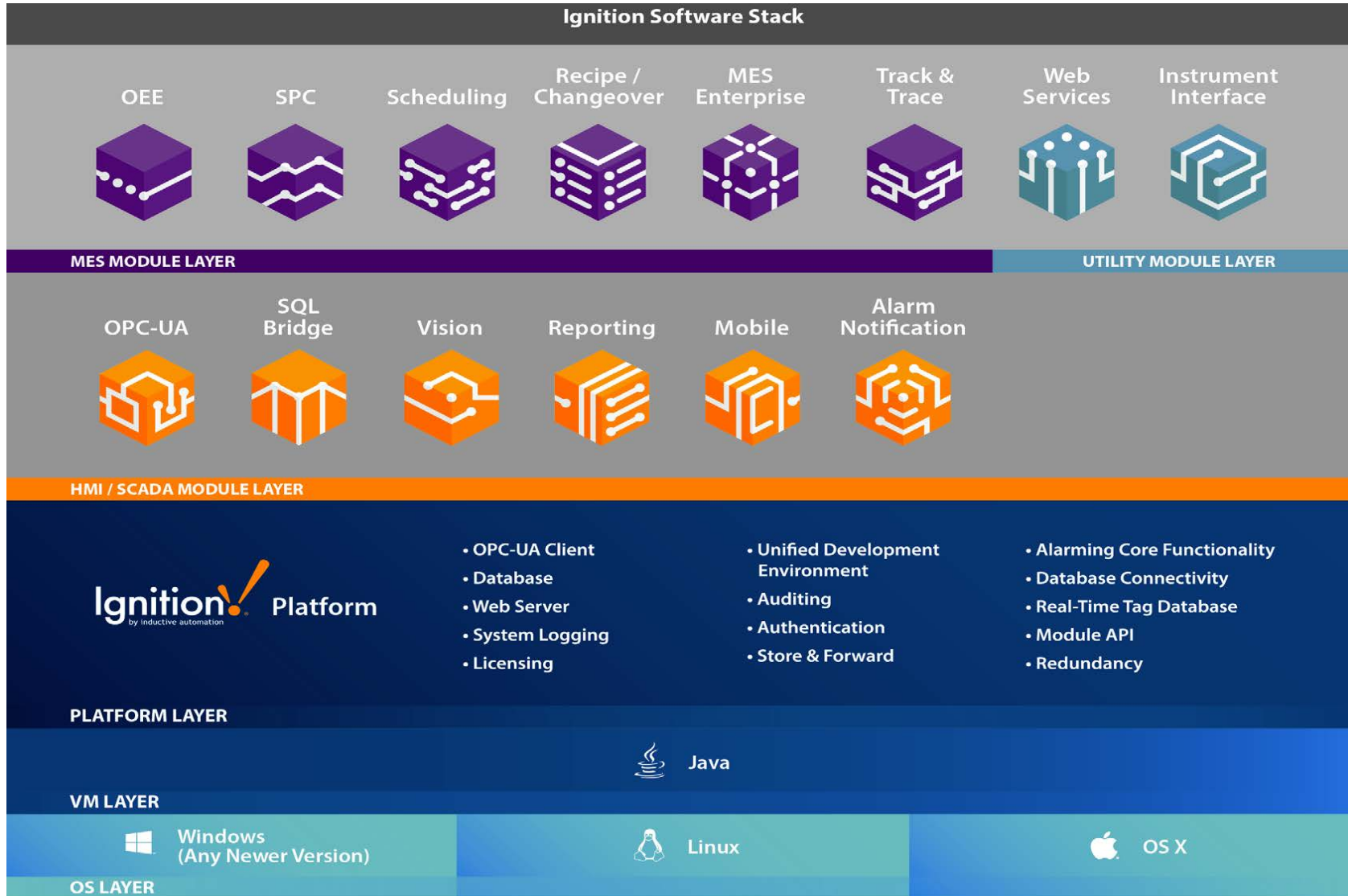
- ✓ Plataforma de servicios en la nube
- ✓ Suscripciones dependiendo del tipo de servicio a utilizar

Ignition

- ✓ Plataforma escalable de Automatización
- ✓ Basado en web - navegador
- ✓ Arquitecturas IIoT redundantes
- ✓ Conectividad a base de datos
- ✓ Módulos MES disponibles (ISA 95)



Diseño del Sistema - Plataforma Ignition



OS LAYER

- Windows/Linux

PLATFORM LAYER

- OPC-UA
- Database
- Authentication
- Redundancy

HMI/SCADA LAYER

- Vision
- Alarm Notification

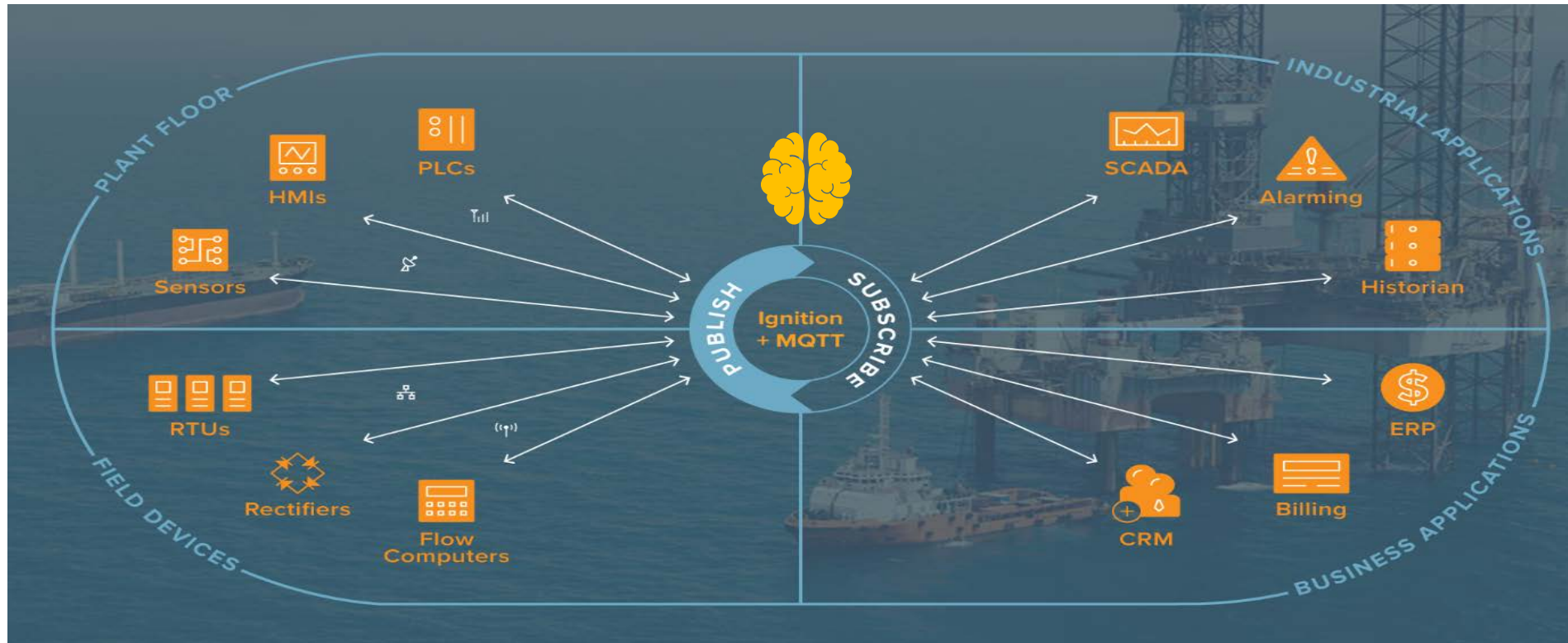
MES MODULE LAYER (SEPASOFT)

- MES Enterprise
- Recipe

IIoT MODULES (CYRRUSLINK)

- Transmission, Distributor, Engine

Diseño del Sistema - IIoT / MQTT



MQTT



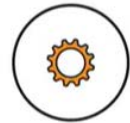
BI-DIRECTIONAL



LOW BANDWIDTH



SECURE



STATEFUL



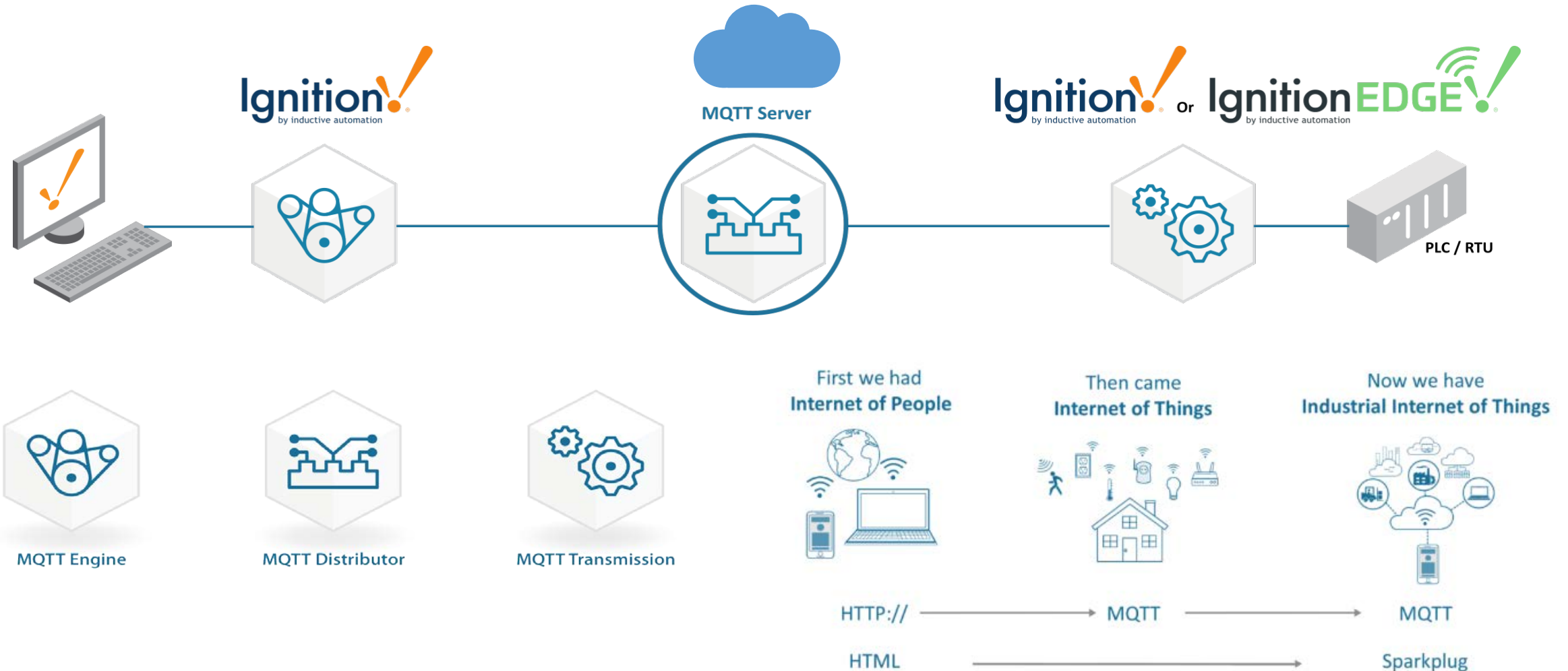
Sparkplug

MQTT Topic & Payload Definition

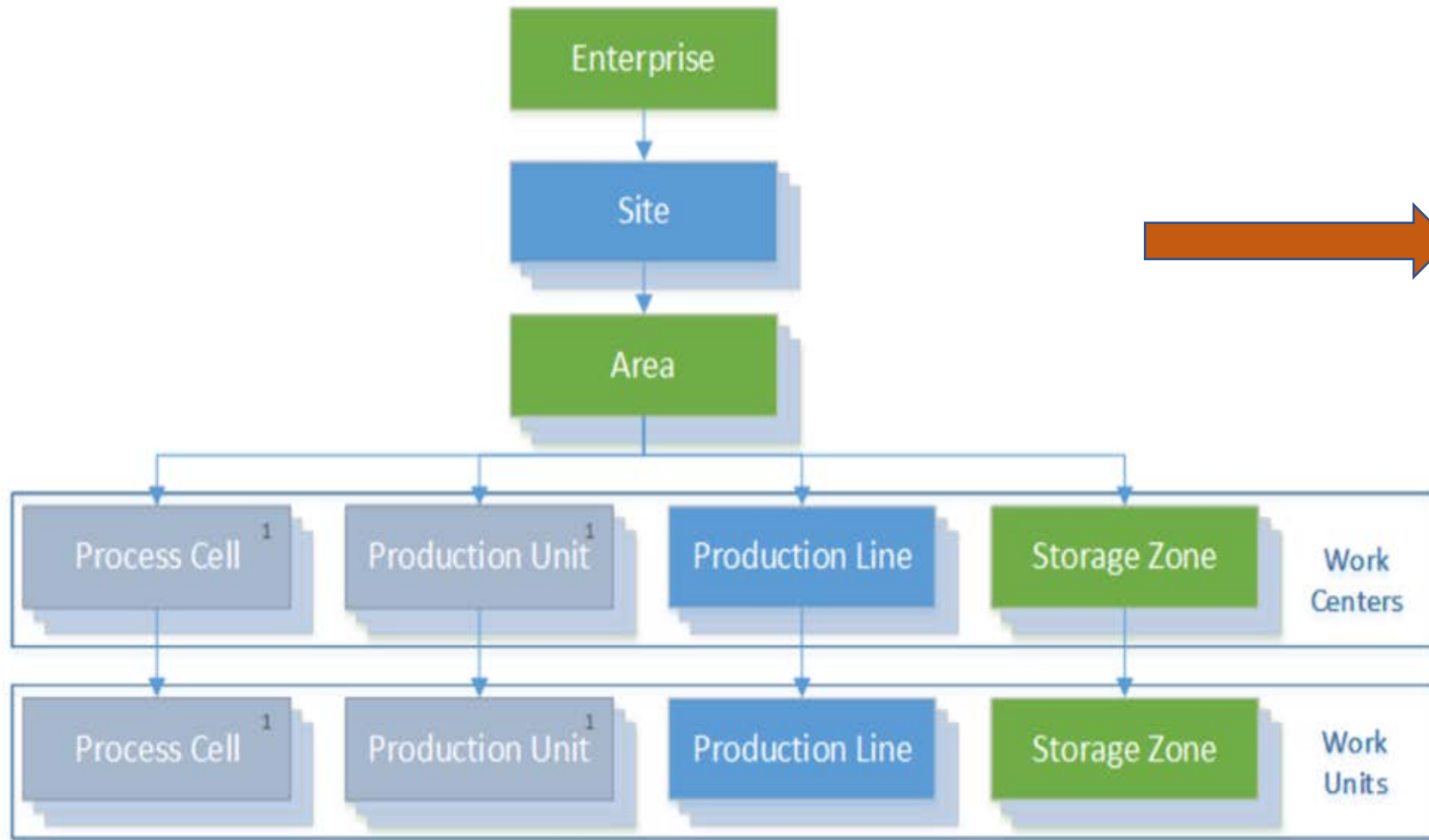


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Diseño del Sistema - Módulos IloT Ignition

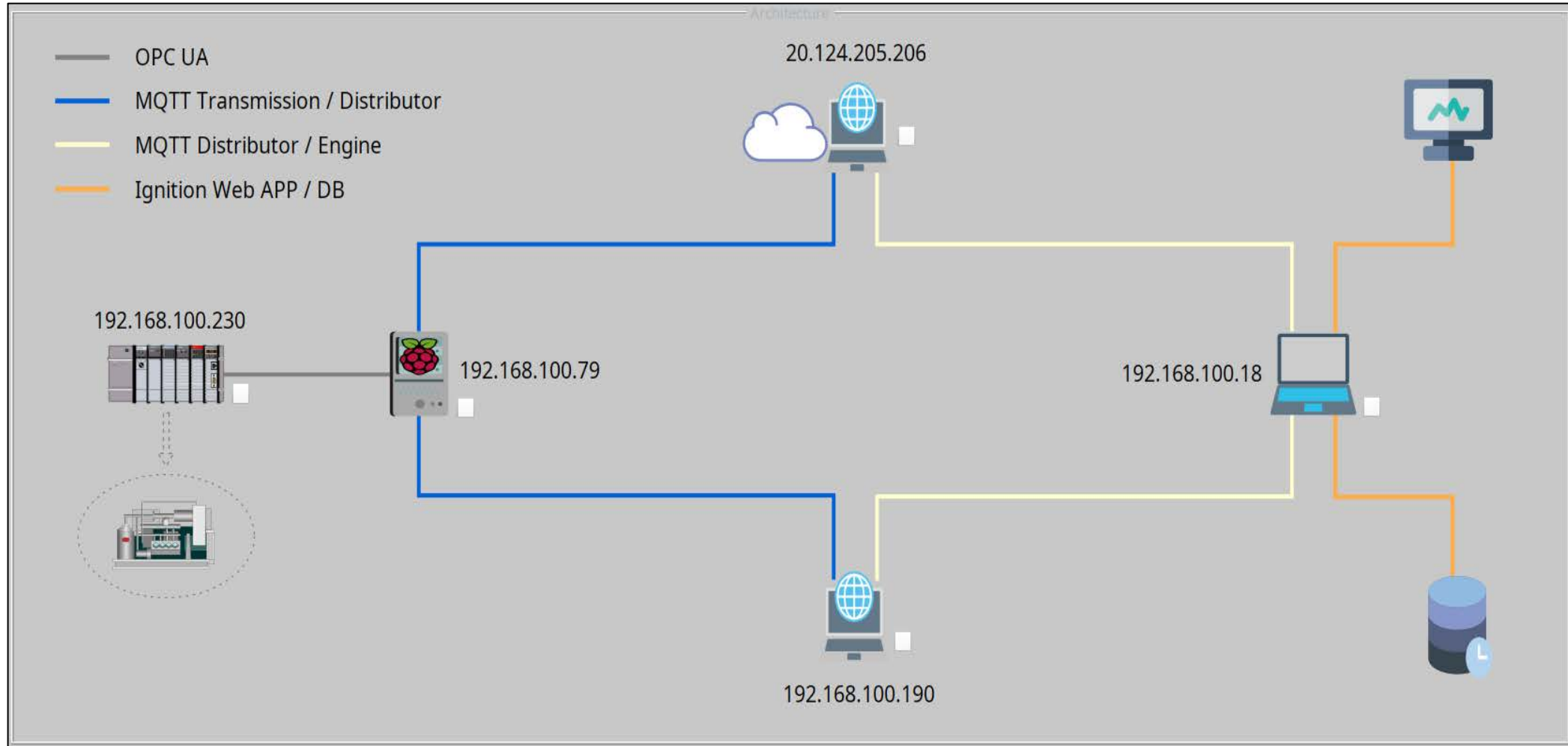


Diseño del Sistema – ISA 95 / Base de datos



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Diseño del Sistema - Arquitectura IIoT



Diseño del Sistema – Direccionamiento IP

Ítem	Equipo	Aplicación	Dirección IP	Máscara de subred
1	TOSHIBA-PC	PLC SoftLogix	192.168.100.230	255.255.255.0
		<i>Broker</i> MQTT respaldo	192.168.100.190	255.255.255.0
2	Raspberry PI	Publicador MQTT	192.168.100.79	255.255.255.0
3	DELL INSPIRON	Receptor MQTT	192.168.100.18	255.255.255.0
4	Servidor <i>Cloud</i> MQTT-1	<i>Broker</i> MQTT primario	20.124.205.206	255.255.255.0

Implementación – Factory IO



Implementación – Factory IO



Implementación – Factory IO

← CONFIGURACIÓN

Advantech USB 4704 & USB 4750

Allen-Bradley Logix5000

Allen-Bradley Micro800

Allen-Bradley MicroLogix

Allen-Bradley SLC 5/05

Automgen Server

Control I/O

MHJ

Modbus TCP/IP Client

Modbus TCP/IP Server

OPC Client DA/UA

Siemens LOGO!

Siemens S7-200/300/400

Siemens S7-1200/1500

Autómata

Autoconexión

Host: 192.168.100.230

Slot / Path: 3

I/O Terminales

	Prefijo	Offset	Cuenta
Entradas Bool	BOOL_IN_	0	130
Salidas Bool	BOOL_OUT_	0	70
Entradas Float	FLOAT_IN_	0	2
Salidas Float	FLOAT_OUT_	0	12
Entradas Int	INT_IN_	0	10
Salidas Int	INT_OUT_	0	10

← DRIVER Allen-Bradley Logix5000

DESCONECTAR CONFIGURACIÓN LIMPIAR

SENSORES

Host: 192.168.100.230

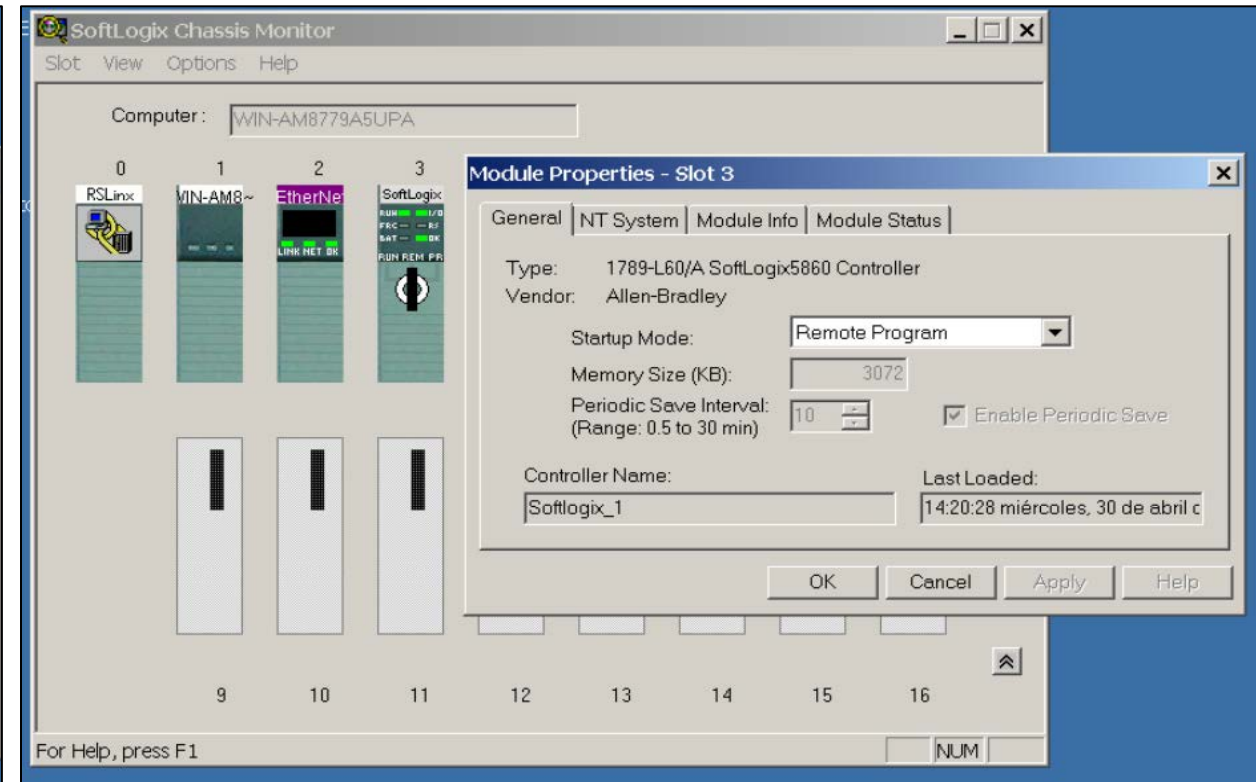
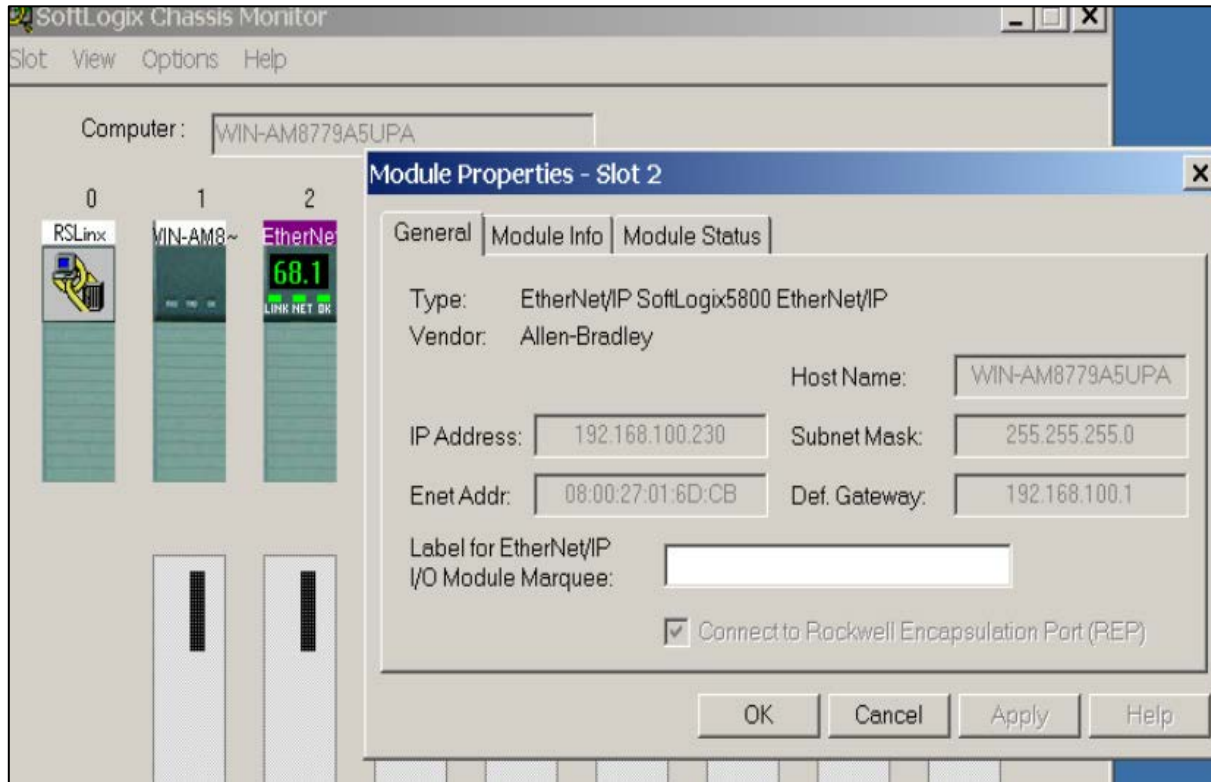
BOD.ALM.PE_01	L1.BT1.PE_01	BOOL_IN_0	BOOL_OUT_0	L1.BT1.IN_1
BOD.ALM.PE_02	L1.BT2.PE_01	BOOL_IN_1	BOOL_OUT_1	L1.BT1.IN_2
BOD.ALM.PE_03	L1.BT4.PE_01	BOOL_IN_2	BOOL_OUT_2	L1.BT2.MS
BOD.ALM.PE_04	L1.BT4.PE_02	BOOL_IN_3	BOOL_OUT_3	L1.BT3.MS
BOD.ALM.PE_05	L1.BT5.LS_01	BOOL_IN_4	BOOL_OUT_4	L1.BT3.SV
BOD.ALM.PE_06	L1.BT6.PE_01	BOOL_IN_5	BOOL_OUT_5	L1.BT5.MS
BOD.ALM.PE_07	L1.BT7.PE_01	BOOL_IN_6	BOOL_OUT_6	L1.BT5.SV_01
BOD.ALM.PE_08	L1.ELE.PX_01	BOOL_IN_7	BOOL_OUT_7	L1.BT5.SV_02
BOD.ALM.PE_09	L1.ELE.PX_02	BOOL_IN_8	BOOL_OUT_8	L1.BT6.IN_01
BOD.ALM.PE_10	L1.ELE.PE_01	BOOL_IN_9	BOOL_OUT_9	L1.BT7.OUT
BOD.ALM.PE_11	L1.ELE.MOV	BOOL_IN_10	BOOL_OUT_10	L1.BT7.MS
BOD.ALM.PE_12	L1.PALLS_01	BOOL_IN_11	BOOL_OUT_11	L1.ELE.MS_TOP
BOD.ALM.PE_13	L1.PALLS_02	BOOL_IN_12	BOOL_OUT_12	L1.ELE.FW
BOD.ALM.PE_14	L1.GIR.PX_01	BOOL_IN_13	BOOL_OUT_13	L1.ELE.RV
BOD.ALM.PE_15	L1.GIR.PX_02	BOOL_IN_14	BOOL_OUT_14	L1.ELE.MS
BOD.ALM.PE_16	L1.GIR.LS_01	BOOL_IN_15	BOOL_OUT_15	L1.PAL.SV_01
BOD.ALM.PE_17	L1.GIR.LS_02	BOOL_IN_16	BOOL_OUT_16	L1.PAL.SV_02
BOD.ALM.PE_18	L2.BT1.PE_01	BOOL_IN_17	BOOL_OUT_17	L1.GIR.MS_IN
BOD.ALM.PE_19	L2.BT2.PE_01	BOOL_IN_18	BOOL_OUT_18	L1.GIR.SV
BOD.ALM.PE_20	L2.BT4.PE_01	BOOL_IN_19	BOOL_OUT_19	L2.BT1.IN_1
BOD.ALM.PE_21	L2.BT4.PE_02	BOOL_IN_20	BOOL_OUT_20	L2.BT1.IN_2
BOD.ALM.PE_22	L2.BT5.LS_01	BOOL_IN_21	BOOL_OUT_21	L2.BT2.MS
BOD.ALM.PE_23	L2.BT6.PE_01	BOOL_IN_22	BOOL_OUT_22	L2.BT3.MS

■ Bool ■ Float ■ Int ■ Cualquiera

ACTUADORES

BOD.BT1.MS
BOD.BT4.OUT
BOD.BT3.MS_AO
BOD.BT4.MS_AO
BOD.R01.POS_0
BOD.R01.POS_1
BOD.R01.POS_2
BOD.R01.POS_3
BOD.R01.POS_4
BOD.R01.POS_5
BOD.R02.POS_0
BOD.R02.POS_1
BOD.R02.POS_2
BOD.R02.POS_3
BOD.R02.POS_4

Implementación – SoftLogix



Implementación – Broker MQTT Cloud

The screenshot displays the Azure portal interface for a virtual machine named "MQTT-1". The left sidebar contains navigation options such as "Información general", "Registro de actividad", "Control de acceso (IAM)", "Etiquetas", "Diagnosticar y solucionar problemas", "Configuración", "Redes", "Conectar", "Discos", "Tamaño", "Microsoft Defender for Cloud", "Recomendaciones de Advisor", "Extensiones + aplicaciones", "Disponibilidad y escalado", and "Configuración".

At the top, there is a search bar and a set of action buttons: "Conectar", "Iniciar", "Reiniciar", "Detener", "Captura", "Eliminar", "Actualizar", "Abrir en dispositivos móviles", "Comentarios", and "CLI / PS".

An advisory message is displayed: "Advisior (1 de 7): Install endpoint protection solution on virtual machines →".

The main content area is divided into three sections:

- Máquina virtual:** A table listing VM details.

Nombre del equipo	MQTT-1
Sistema operativo	Windows
Publicador	MicrosoftWindowsDesktop
Oferta	Windows-10
Plan	win10-21h2-pro-g2
Generación de VM	V2
Arquitectura de VM	x64
Grupo host	Ninguno
Host	-
Grupo con ubicación por proximidad	-
Estado de ubicación	N/D
Grupo de reserva de capacidad	-
Tipo de controladora de disco	SCSI
- Redes:** A table listing network settings.

Dirección IP pública	20.124.205.206 (Interfaz de red mqtt-1389)
Dirección IP pública (IPv6)	-
Dirección IP privada	10.2.0.4
Dirección IP privada (IPv6)	-
Red virtual/subred	MQTT-1-vnet/default
Nombre DNS	Configurar
- Tamaño:** A table listing VM size specifications.

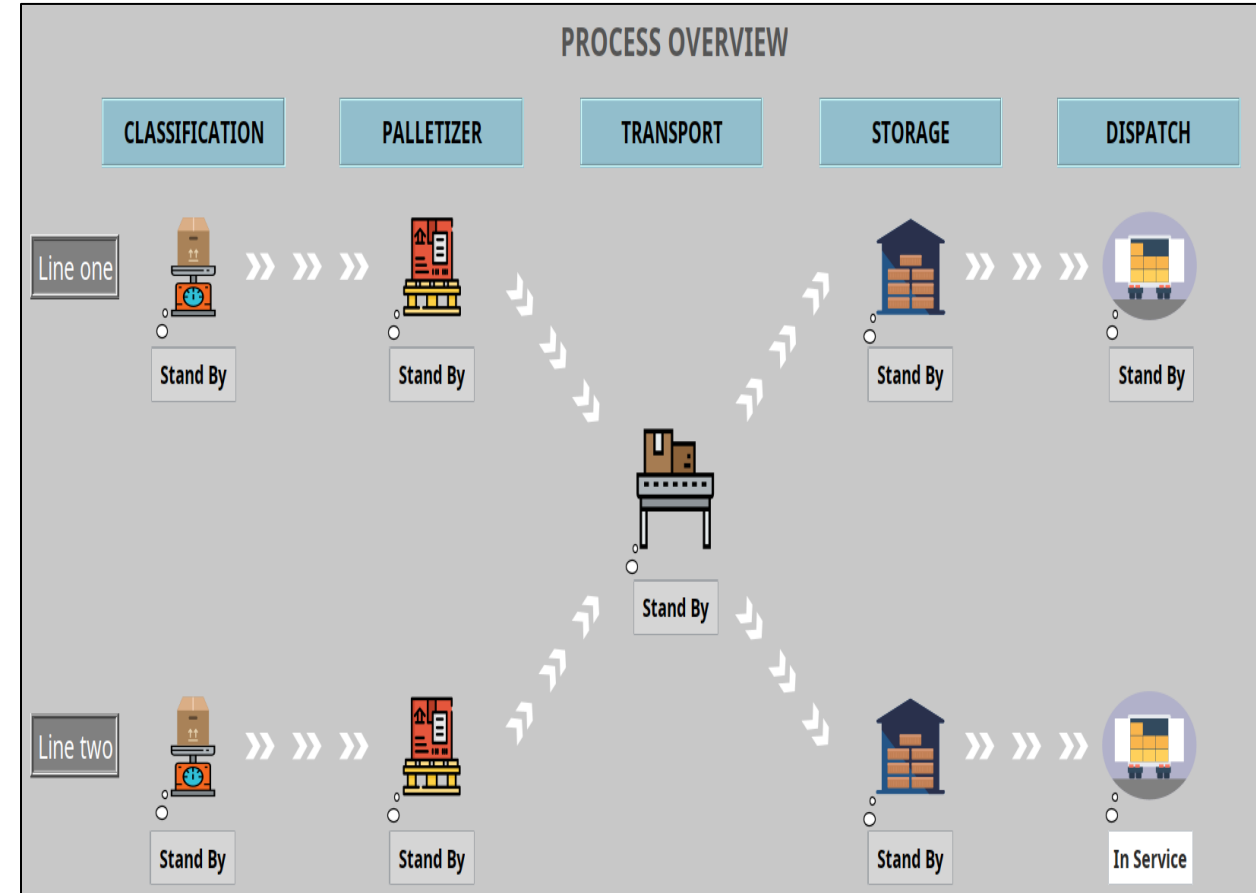
Tamaño	Standard B2s
vCPU	2
RAM	4 GiB
- Disco:** A table listing disk settings.

Disco del SO	MQTT-1_disk1_ee915c647f2a447b8871a9f20fcdd6cd
Cifrado en el host	Deshabilitado
Azure Disk Encryption	No habilitado

Implementación – Aplicación SCADA / MES

CLOUD BROKER		ENGINE NODE	
Target Server URL	tcp://20.124.205.206:1883	Current Server	LAN-BROKER
Online DateTime	1 may. 2023 0:05:29	Online DateTime	1 may. 2023 0:11:20
Offline DateTime		Offline DateTime	1 may. 2023 0:08:48
Connected nodes	0	Last node to Connect	TESIS/EDGE_ARM
Messages per second	0	Total Data Mesg Count	1.355
Online	ON	Devices Online	1

LAN BROKER		EDGE NODE	
Target Server URL	tcp://192.168.100.190:1883	Message Schema	Sparkplug B v1.0
Online DateTime	1 may. 2023 0:05:42	PLC Description	PLC for palletizer project
Offline DateTime		OPC State	CONNECTED
Connected nodes	1	System Name	Ignition-raspberrypi
Messages per second	0	Hostname	192.168.100.230
Online	ON	Online	ON



Implementación – Aplicación SCADA / MES

Line One

Parameters

Setpoint Kg

Box size Regular Oversize

Motors Status

Box feeder	Passed	2.243
Electronic scale	Rejected	27
Out conveyor	Total	2.243

Data

START

0 Kg

Motor Fail

Reset

Line Two

Parameters

Setpoint Kg

Box size Regular Oversize

Motors Status

Box feeder	Passed	4.982
Electronic scale	Rejected	181
Out conveyor	Total	4.982

Data

START

0 Kg

Motor Fail

Reset

Line One

Motors Status

- Boxes conveyor
- Pallet conveyor
- Elevator
- Out conveyor

Parameters

Rows	Quantity
<input type="text" value="1"/>	<input type="text" value="3"/>

Data

Setpoint	1
Total	0

Conv 1 Fail

Conv 2 Fail

Reset

Product ID

0

High 100

75

50

25

Low 0

Line Two

Motors Status

- Boxes conveyor
- Pallet conveyor
- Elevator
- Out conveyor

Parameters

Rows	Quantity
<input type="text" value="1"/>	<input type="text" value="2"/>

Data

Setpoint	1
Total	0

Conv 1 Fail

Conv 2 Fail

Reset

Product ID

0

High 100

75

50

25

Low 0

Implementación – Aplicación SCADA / MES

The SCADA interface displays a production line with two lines, LINE TWO and LINE ONE. LINE TWO is at the top and LINE ONE is at the bottom. The interface includes a 'Motors Status' section with four indicators: Inlet conveyor, Outlet conveyor, Storage robot, and Dispatch robot. There are two vertical gauges labeled L1 and L2, each with a scale from 0 to 25 and a red line indicating the current level. The 'Parameters' section includes buttons for 'Line One', 'Off', and 'Line Two', along with a 'Start' button and a counter showing '3'.

Active Time	Clear Time	Display Path	Current State	Active Duration	Priority
1/5/23 0:39	1/5/23 0:41	CLOUD BROKER COMM LOST	Cleared, Unacknowledged	1 minutes, 58 seconds	Critical
30/4/23 22:03	1/5/23 0:11	OPC UA Communication lost	Cleared, Unacknowledged	2 hours, 8 minutes, 1 seconds	Critical
1/5/23 0:08	1/5/23 0:11	MQTT Engine Communication lost	Cleared, Unacknowledged	2 minutes, 30 seconds	Critical
1/5/23 0:08	1/5/23 0:11	Raspberry PI Communication lost	Cleared, Unacknowledged	2 minutes, 30 seconds	Critical
1/5/23 0:03	1/5/23 0:06	MQTT Engine Communication lost	Cleared, Unacknowledged	3 minutes, 30 seconds	Critical
1/5/23 0:03	1/5/23 0:06	Raspberry PI Communication lost	Cleared, Unacknowledged	3 minutes, 29 seconds	Critical
1/5/23 0:03	1/5/23 0:05	LAN BROKER COMM LOST	Cleared, Unacknowledged	2 minutes, 24 seconds	Critical
1/5/23 0:03	1/5/23 0:05	CLOUD BROKER COMM LOST	Cleared, Unacknowledged	2 minutes, 12 seconds	Critical
30/4/23 23:11	30/4/23 23:11	MQTT Engine Communication lost	Cleared, Unacknowledged	4 seconds	Critical
30/4/23 23:11	30/4/23 23:11	Raspberry PI Communication lost	Cleared, Unacknowledged	4 seconds	Critical
30/4/23 23:11	30/4/23 23:11	LAN BROKER COMM LOST	Cleared, Unacknowledged	2 seconds	Critical
30/4/23 22:04	30/4/23 22:39	CLOUD BROKER COMM LOST	Cleared, Unacknowledged	35 minutes, 9 seconds	Critical
30/4/23 22:03	30/4/23 22:04	MQTT Engine Communication lost	Cleared, Unacknowledged	42 seconds	Critical
30/4/23 22:03	30/4/23 22:04	Raspberry PI Communication lost	Cleared, Unacknowledged	41 seconds	Critical
30/4/23 22:02	30/4/23 22:03	LAN BROKER COMM LOST	Cleared, Unacknowledged	50 seconds	Critical
30/4/23 22:02	30/4/23 22:03	MQTT Engine Communication lost	Cleared, Unacknowledged	40 seconds	Critical
30/4/23 22:02	30/4/23 22:03	Raspberry PI Communication lost	Cleared, Unacknowledged	39 seconds	Critical

Implementación – Aplicación SCADA / MES

The screenshot displays a software interface for recipe management. On the left, a tree view shows the hierarchy: Recipes > L1 EXTRACTOR SP1 > PALLETIZER > LINE ONE > EXTRACTOR ROBOT. Below this, a table lists recipe settings for 'L1 EXTRACTOR SP1'.

Name	Value	Units	Assigned By
L1 EXTRACTOR SP	5		EXTRACTOR ROBOT - ...

The main area contains several control panels for 'Line One' and 'Line Two' for 'Weight', 'Palletizer', and 'Extraction'. Each panel has a 'Live' indicator (yellow lightbulb) and a 'Manual' indicator (green arrow). Below these are search boxes for 'Line', 'Cell', and 'SP'. At the bottom, a table shows the current state of the recipe.

Name	Recipe Setting	Live Value	Manual Value	Description
L1 EXTRACTOR SP	5	3	5	

The screenshot shows a 'Recipe' configuration window with tabs for 'General', 'OEE Downtime 2.0', 'Quality', 'Recipe', 'Trace', and 'Advanced'. The 'Recipe' tab is active, showing a tree view of the recipe structure and a table of recipe values.

Recipe Values Table:

Name	Description	Tag	Request V...	Enable Sc...	Enable Va...
L2 PALLETS SP		[default]SF ...		true	true
L2 ROW PALLETIZER SP		[default]SF ...		true	true

The bottom right panel shows the 'Status' and 'Events' section, indicating the recipe is 'Running' and providing execution details.

Status: Running
Alert:
Last Execution Time: 12:58:54 a. m.
Last Execution Durabon: < 1 ms
Maximum Execution Durabon:
Local Datasource: DB_MY_SQL_CONNECTION
Analysis Datasource: DB_MY_SQL_CONNECTION

Pruebas de funcionamiento – Conectividad

PRUEBA DE CONECTIVIDAD ICMP

Equipo origen	Equipo destino	Velocidad (ms)
	192.168.100.230	4
Ignition Gateway	192.168.100.190	4
192.168.100.18	192.168.100.79	9
	20.124.205.206	105

RECETAS PARA LÍNEAS DE PALETIZADO

	Pesaje (kg)	Pallets (u)	Filas de cajas (u)	Despacho (u)
Línea Uno	3	3	1	3
Línea Dos	3	2	1	5



Pruebas de funcionamiento – Redundancia

CLOUD BROKER	
Target Server URL	tcp://20.124.205.206:1883
Online DateTime	1 may. 2023 11:10:15
Offline DateTime	1 may. 2023 11:10:15
Connected nodes	1
Messages per second	0,5
Online	ON

ENGINE NODE	
Current Server	CLOUD-BROKER
Online DateTime	1 may. 2023 11:11:24
Offline DateTime	1 may. 2023 11:11:21
Last node to Connect	TESIS/EDGE_ARM
Total Data Mesg Count	1.887
Devices Online	1

LAN BROKER	
Target Server URL	tcp://192.168.100.190:1883
Online DateTime	1 may. 2023 11:11:23
Offline DateTime	1 may. 2023 11:11:21
Connected nodes	0
Messages per second	0
Online	ON

EDGE NODE	
Message Schema	Sparkplug B v1.0
PLC Description	PLC for palletizer project
OPC State	CONNECTED
System Name	Ignition-raspberrypi
Hostname	192.168.100.230
Online	ON

CLOUD BROKER	
Target Server URL	tcp://20.124.205.206:1883
Online DateTime	1 may. 2023 11:14:19
Offline DateTime	1 may. 2023 11:14:50
Connected nodes	0
Messages per second	0
Online	OFF

ENGINE NODE	
Current Server	LAN-BROKER
Online DateTime	1 may. 2023 11:14:20
Offline DateTime	1 may. 2023 11:14:19
Last node to Connect	TESIS/EDGE_ARM
Total Data Mesg Count	1.998
Devices Online	1

LAN BROKER	
Target Server URL	tcp://192.168.100.190:1883
Online DateTime	1 may. 2023 11:11:23
Offline DateTime	1 may. 2023 11:11:21
Connected nodes	1
Messages per second	0,5
Online	ON

EDGE NODE	
Message Schema	Sparkplug B v1.0
PLC Description	PLC for palletizer project
OPC State	CONNECTED
System Name	Ignition-raspberrypi
Hostname	192.168.100.230
Online	ON

Active Time	Display Path	Current State	Priority	Active Duration
1/5/23 11:14	CLOUD BROKER COMM LOST	Active, Unacknowledged	Critical	17 seconds

Pruebas de funcionamiento – Desconexión IIoT

Legend:

- OPC UA
- MQTT Transmission / Distributor
- MQTT Distributor / Engine
- Ignition Web APP / DB

IPs: 192.168.100.230, 192.168.100.79, 20.124.205.206, 192.168.100.18, 192.168.100.190

Active Time	Display Path	Current State	Priority	Active Duration
1/5/23 11:30	MQTT Engine Communication lost	Active, Unacknowledged	Critical	2 minutes
1/5/23 11:30	Raspberry PI Communication lost	Active, Unacknowledged	Critical	3 minutes

Acknowledge

CLOUD BROKER

Target Server URL: **tcp://20.124.205.206:1883**

Online DateTime: **1 may. 2023 11:20:38**

Offline DateTime: **1 may. 2023 11:20:38**

Connected nodes: **0**

Messages per second: **0**

Online: **ON**

ENGINE NODE

Current Server: **LAN-BROKER**

Online DateTime: **1 may. 2023 11:14:20**

Offline DateTime: **1 may. 2023 11:30:28**

Last node to Connect:

Total Data Mesg Count: **2.619**

Devices Online: **0**

LAN BROKER

Target Server URL: **tcp://192.168.100.190:1883**

Online DateTime: **1 may. 2023 11:11:23**

Offline DateTime: **1 may. 2023 11:11:21**

Connected nodes: **0**

Messages per second: **0**

Online: **ON**

EDGE NODE

Message Schema: **Sparkplug B v1.0**

PLC Description: **C for palletizer project**

OPC State: **DISCONNECTED**

System Name: **Ignition-raspberrypi**

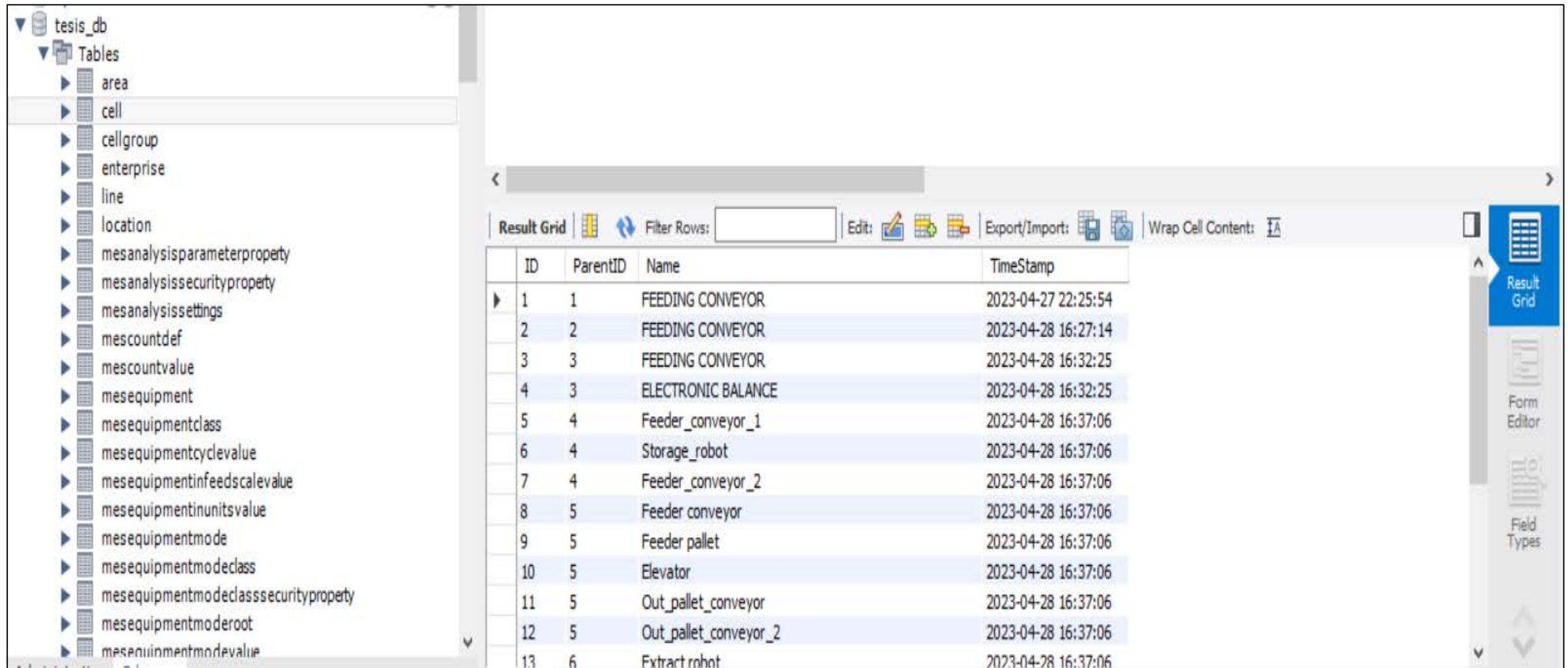
Hostname: **192.168.100.230**

Online: **OFFLINE**

Active Time	Display Path	Current State	Priority	Active Duration
1/5/23 11:30	MQTT Engine Communication lost	Active, Unacknowledged	Critical	3 minutes
1/5/23 11:30	Raspberry PI Communication lost	Active, Unacknowledged	Critical	3 minutes

Acknowledge

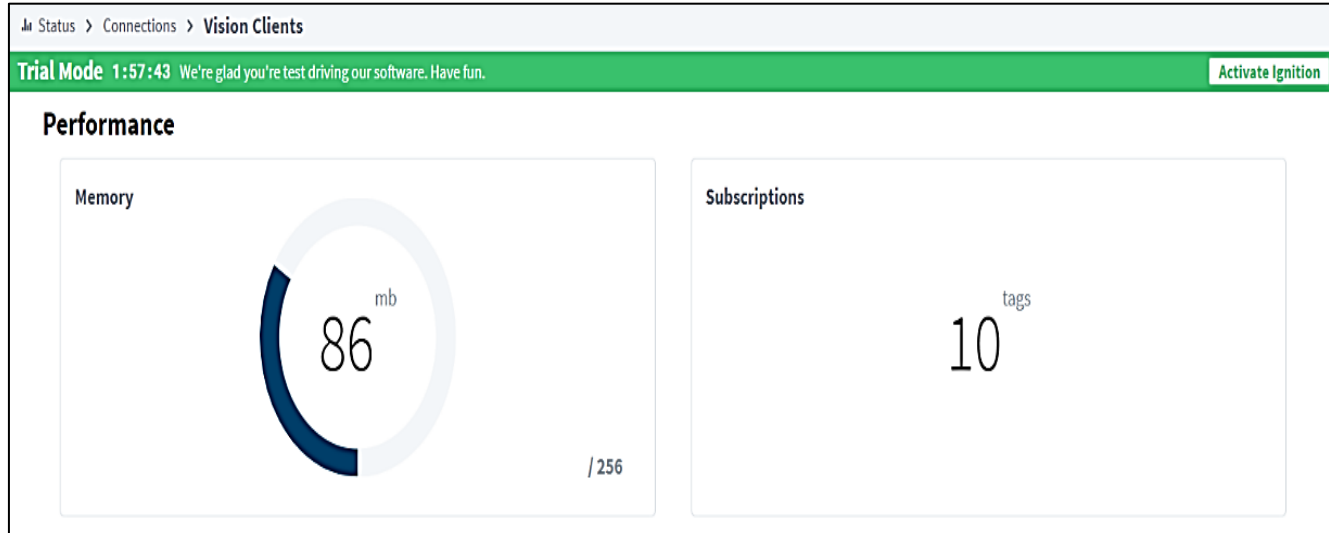
Pruebas de funcionamiento – Base de datos



The screenshot displays a database management interface. On the left, a tree view shows the database structure under 'tesis_db', with 'Tables' expanded to show a list of tables including 'area', 'cell', 'cellgroup', 'enterprise', 'line', 'location', and various 'mesequipment' related tables. The main area shows a 'Result Grid' with a table of equipment data. The table has columns for ID, ParentID, Name, and TimeStamp. The data rows are as follows:

ID	ParentID	Name	TimeStamp
1	1	FEEDING CONVEYOR	2023-04-27 22:25:54
2	2	FEEDING CONVEYOR	2023-04-28 16:27:14
3	3	FEEDING CONVEYOR	2023-04-28 16:32:25
4	3	ELECTRONIC BALANCE	2023-04-28 16:32:25
5	4	Feeder_conveyor_1	2023-04-28 16:37:06
6	4	Storage_robot	2023-04-28 16:37:06
7	4	Feeder_conveyor_2	2023-04-28 16:37:06
8	5	Feeder conveyor	2023-04-28 16:37:06
9	5	Feeder pallet	2023-04-28 16:37:06
10	5	Elevator	2023-04-28 16:37:06
11	5	Out_pallet_conveyor	2023-04-28 16:37:06
12	5	Out_pallet_conveyor_2	2023-04-28 16:37:06
13	6	Extrac robot	2023-04-28 16:37:06

Pruebas de funcionamiento – Desempeño



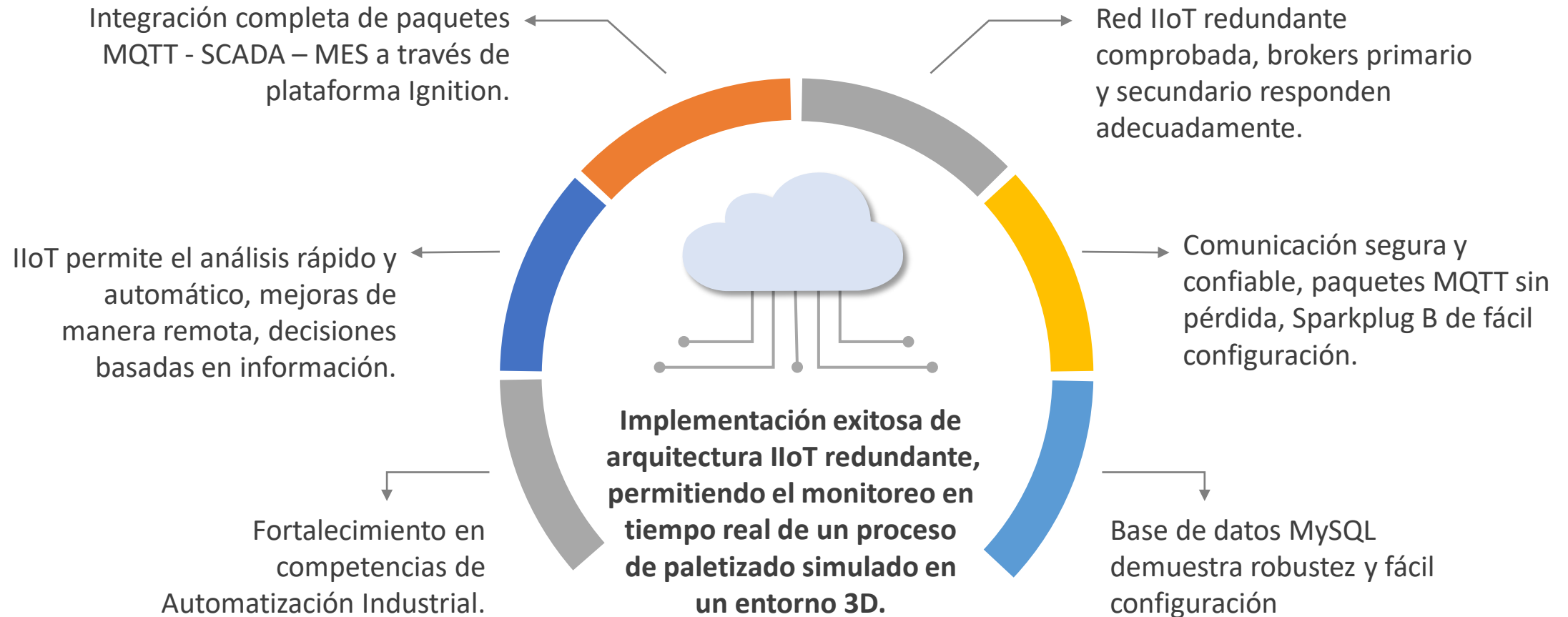
Details

Session Details	
User	MrDowsebf
Project	MESGateway
Address	DESKTOP-ULDRHCJ (127.0.0.1)
Uptime	2 minutes
Last Comm	295ms
Client JVM Version	11.0.11

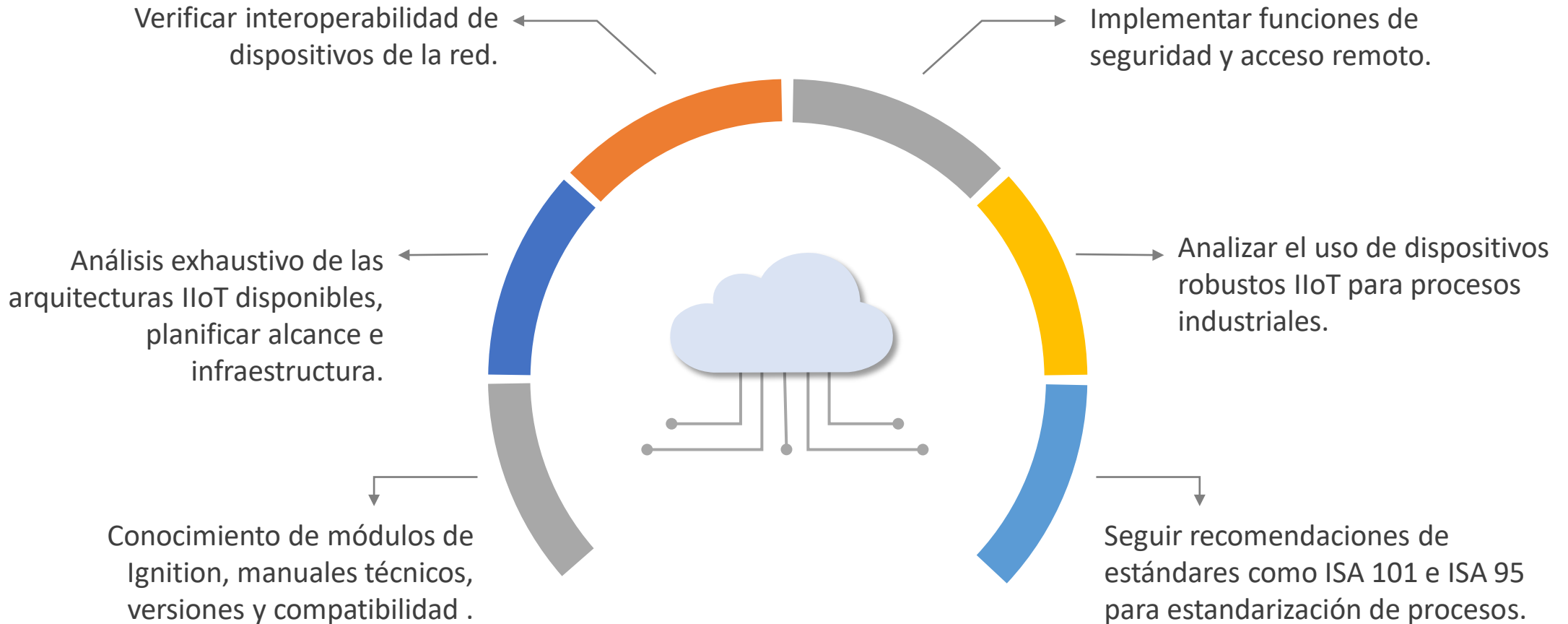
Parámetros de red IIoT (tiempo real)

Pantalla	Tags	Uso de memoria (Mb)	Velocidad (ms)
Topología	10	78	325
Parámetros	66	79	299
MES	66	81	277
Vista general	84	87	165
Pesaje	123	93	297
Paletizado	160	90	229
Almacenamiento	240	94	361
Alarmas	240	97	126

Conclusiones



Recomendaciones





¡¡¡GRACIAS!!!



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