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EPICS : Powerful middleware for Industrial Automation and IoT

White Paper

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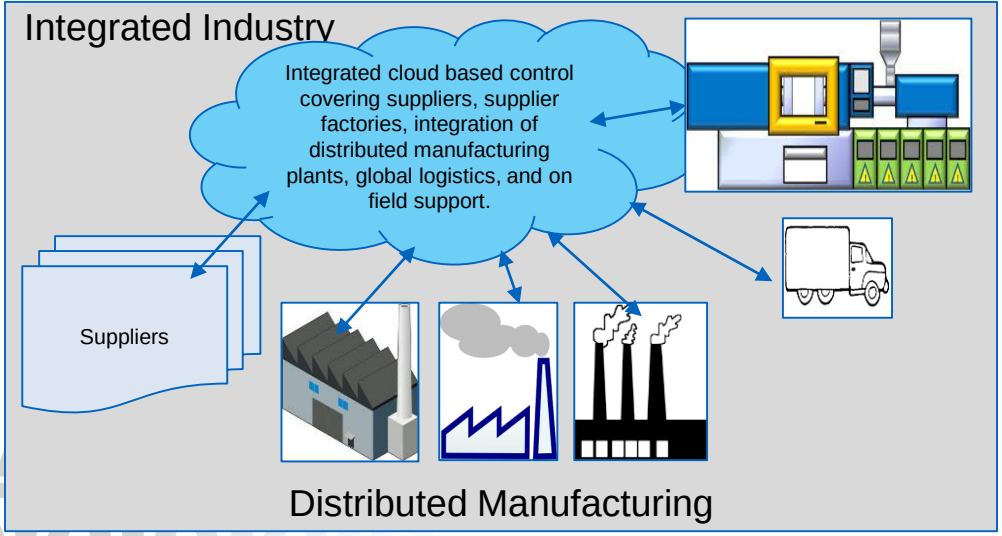
Trends in Industrial Automation

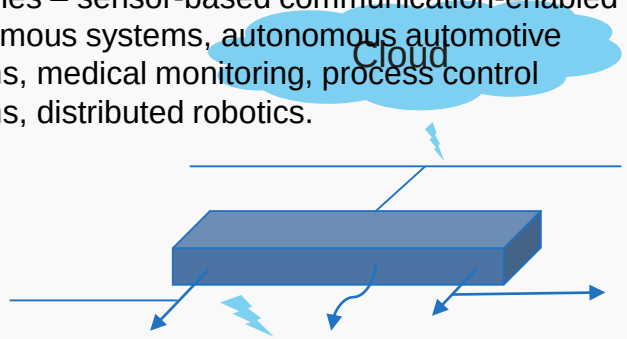
4’th Industrial revolution/ Industry 4.0

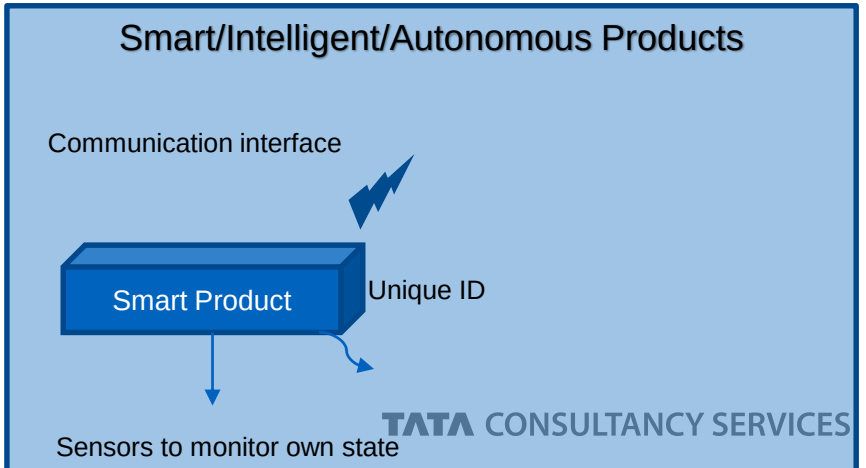
- Integrated Industry
  - right from customer order placement to sourcing, manufacturing, logistics and on-field maintenance.
- Adaptive Manufacturing
  - Smart Factory-Flexible and De-centralized, Make to Order, Mass Customization
  - Realization of distributed and networked production methods.
- Cyber Physical Systems (CPS)-networking of embedded ICT systems both with one another and with the Internet.
- Intelligent monitoring and autonomous decision-making processes



Cyber physical Systems

- Embedded systems to connect the Cyber world to physical world
- Customized systems
- Connect sensors, actuators etc.
- Real time, Intelligent,
- Autonomous
- Cyber Security
- Examples – sensor-based communication-enabled autonomous systems, autonomous automotive systems, medical monitoring, process control systems, distributed robotics.

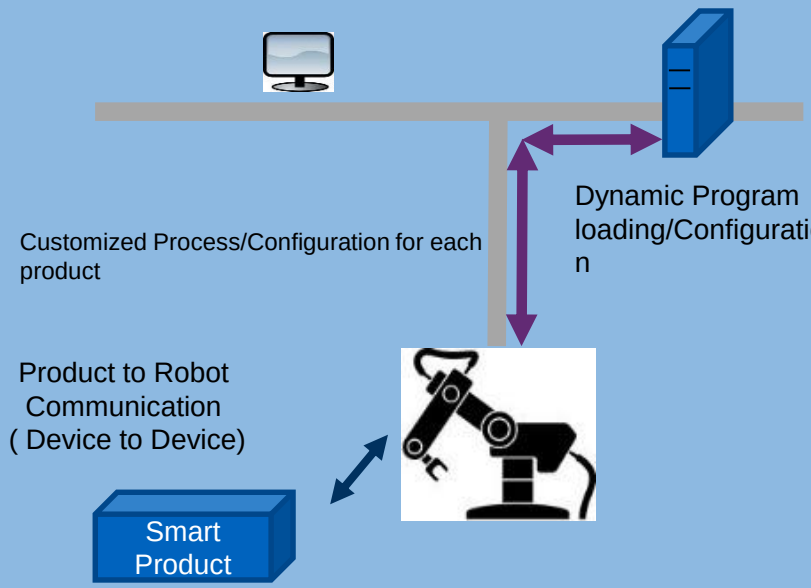




Trends in Industrial Automation

- Unified Enterprise wide automation systems,
  - connecting together the various individual control systems used in the enterprise
  - Digitally networked production plants
- Collapsing Architecture- Direct connectivity from MES, ERP to Factory level.
- Distributed control-More control logic on Edge
- More Intelligent systems, PC as controllers, Vision based systems, Machine learning, Intelligent autonomous systems
- Ethernet converging as the common medium on all layers
- More Sensors, More Data, Big Data, more data traffic, hence faster systems.
- IPv6
- Cloud connectivity
- Retrofit & Upgrade
- Standards conformance
- Data security
- Safety
- Environment

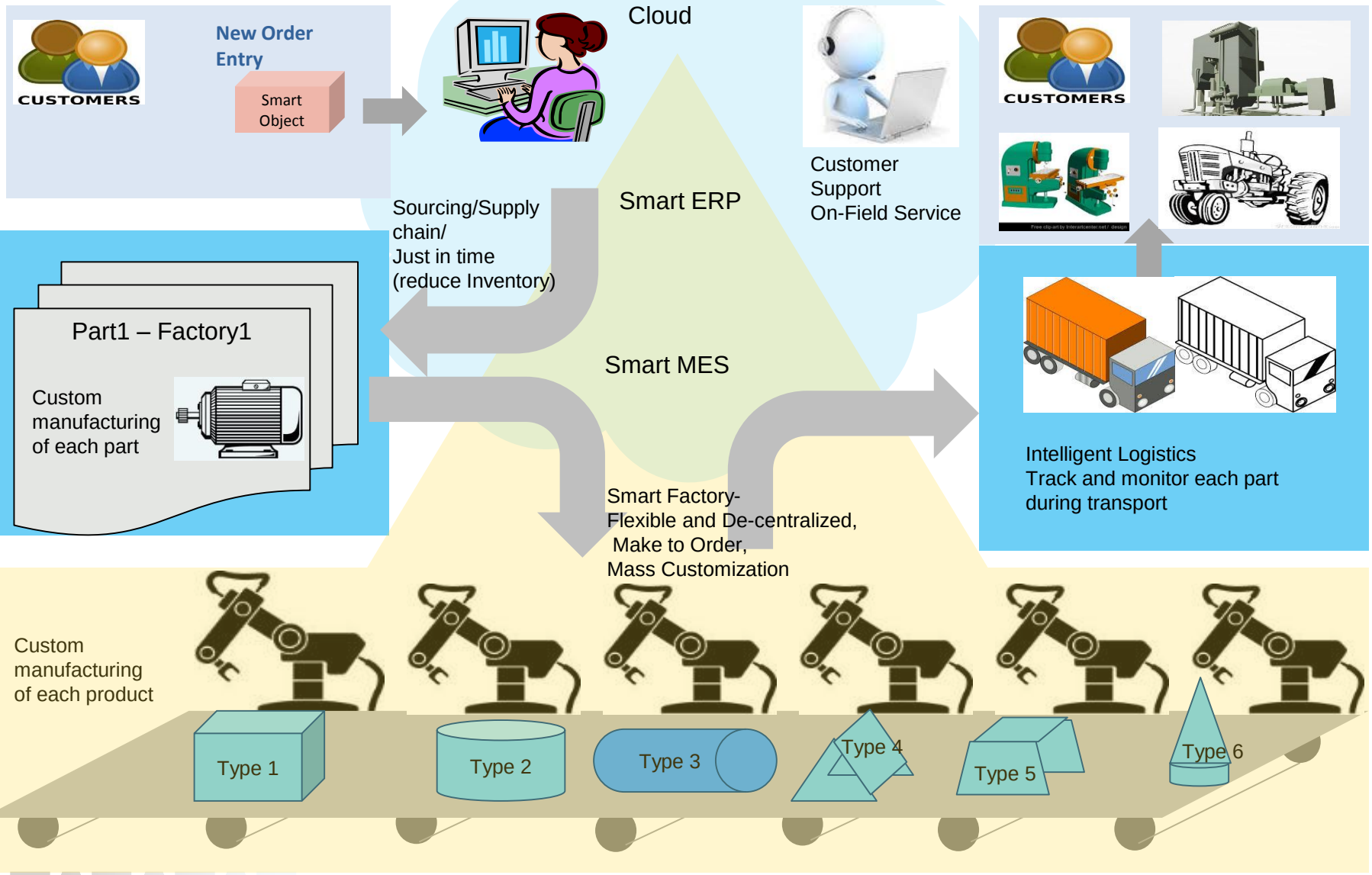
Smart/Intelligent Products for Adaptive Manufacturing



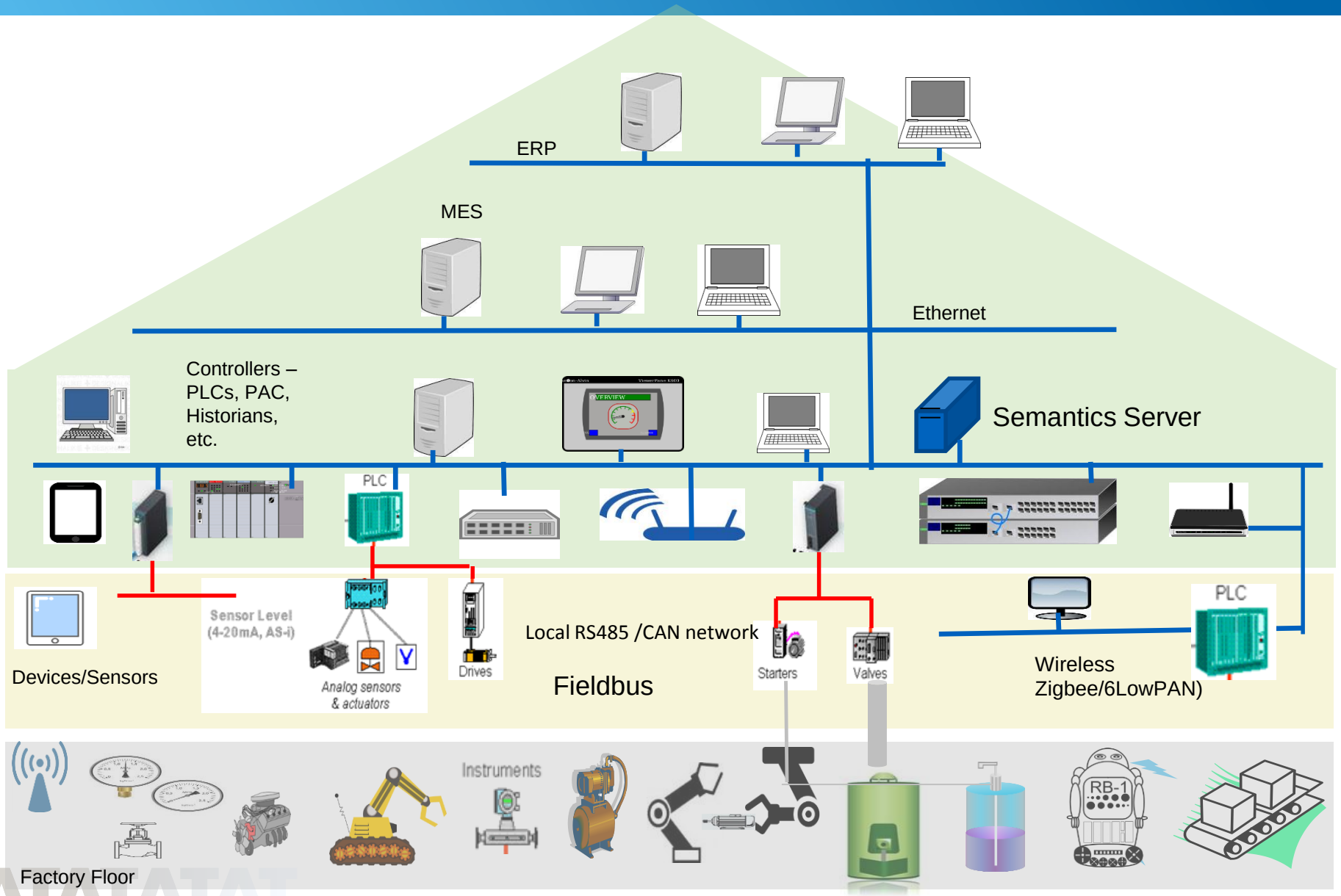
Device Programming and Configuration

Specific configuration for each unit/product

Emerging manufacturing Scenario - Adaptive Manufacturing



New Factory Automation Landscape – Heterogeneous Systems



Fieldbuses

Process Control

- CC-Link
- CIP (Common Industrial Protocol) DeviceNet, CompoNet , ControlNet and EtherNet/IP
- CAN (Controller Area Network)-- including CANopen and DeviceNet
- EtherCAT
- Ethernet Powerlink
- Foundation Fieldbus
- HART
- Modbus
- Profibus
- SERCOS
- RS232/485/422

Building Automation

- Modbus
- Lontalk
- RS232/485/422

Robotics

- RS232/485/422
- EthercAT
- CANOpen
- Modbus

Automotive/Vehicle

- CAN
- LIN
- FlexRay
- MOST
- LON
- LSI
- RS232/485/422

Automatic Meter reading

- Modbus
- M-bus
- Zigbee-Smart Energy

Wireless

- Zigbee
- Wifi
- Buetooth

Ethernet based Fieldbuses

- PROFINET
- EtherNet/IP
- CC-Link-IP
- Sercos III
- Powerlink
- Modbus/TCP
- EtherCAT

Type	Examples
• Standard Ethernet Controllers/Switches • Standard TCP/UDP/IP stack	• Profinet(CbA) • EtherNet/IP • Modbus-IDA
• Standard Ethernet Controllers/Switches • Specialized TCP/UDP/IP stack	• ProfiNet(RT) • Powerlink
• Specialized Real Time Ethernet Controllers/switches • Specialized TCP/UDP/IP stack	• ProfiNet(IRT) • CC-Link-IE • Sercos III • EtherCAT

Ethernet in Factory Automation

Sr.No.	Advantages of Device buses over Ethernet based buses	Advantages of Ethernet based protocols
1	Deterministic	Faster
2	Less Sensitive to electrical noise	Same network of IT and automation. Connecting with standard Ethernet makes these systems more interoperable.
3	Easier to transmit power over the network	Easier to expand
4		Universal connectivity to controllers, I/O and other components
5		Ability to transmit multiple protocols simultaneously.
6		Superior and rapidly improving price/performance ratio
7		Easy integration with multiple wireless networks
8		Ethernet technology is rapidly being embraced and promoted by multiple fieldbus standards organizations, including Profibus International (PI),Open DeviceNet Vendor Association (ODVA), CANopen, Modbus.org, Fieldbus Foundation and others.

Ethernet for real time control

- IEEE 802.3x – Flow Control, Full duplex operation
- IEEE 802.3p – Priority Queuing

Role of Middleware in Factory Automation

- Fieldbus are be more deterministic and real time, but may need to be limited to smaller number of devices inside the machine/robot. This may be due to special hardware required by the Fieldbus and also may be due to the limitations on the number of devices that can be connected.
- Considering Distributed applications and more intelligent edge nodes, communication requirements at some levels, for example between station to station may be soft real time. So, may be Fieldbus requiring special hardware may not be required.
- Considering that the collapsing plant system architecture, and the merging of the plant and the controller levels, having a common protocol may be a better option. This will enable connectivity from MES/ERP to the controllers/devices/products level.
- Middleware can provide a solution for soft/near real time peer to peer communication on standard Ethernet.
- Many middleware provide facility for device discovery, and devices can be added to network and removed from the network on the fly. This goes well with wireless networks, which can lose connection any time
- Middleware may facilitate remote connectivity and remote control as well, due to its inherent features
- Middleware may integrate better with new trends and technologies like IpV6, Big Data, SOA, Semantics etc.
- Middleware may facilitate redundancy, which is important in may safety critical applications

Available Middleware Solutions

- COM/DCOM
- OPC UA
- CORBA
- JAVA RMI /DCE/RPC/ICE/ESB
- TIBCO/JMS(Java Message Service)/MQ Series/ActiveMQ/SoniqMQ
- OMG DDS
  - The OMG Data-Distribution Service for Real-Time Systems (DDS) is the first open international middleware standard directly addressing publish-subscribe communications for real-time and embedded systems.
- MQTT (Message Queue Telemetry Transport)
  - publish – subscribe based "light weight" messaging protocol for use on top of the TCP/IP protocol. It is designed for connections with remote locations where a "small code footprint" is required and/or network bandwidth is limited. The Publish-Subscribe messaging pattern requires a message broker. The broker is responsible for distributing messages to interested clients based on the topic of a message.
- AMQP (Advanced Message Queuing Protocol (AMQP)
  - Open standard application layer protocol for message-oriented middleware. The defining features of AMQP are message orientation, queuing, routing (including point-to-point and publish-and-subscribe), reliability and security
- XMPP (Extensible Messaging and Presence Protocol)
  - Message oriented middleware based on XML(Extensible Markup Language)
- REST/SOAP/WSDL
- EPICS - EPICS is not just a protocol is rather a set of tools built on top of the EPICS Channel Access protocol.

Characteristics of IoT and applicability of EPICS

Sr.No.	Required Characteristics of Industrial Automation/IoT	Advantages of EPICS
1	Heterogeneous Systems in collapsing architecture Framework should facilitate integration of systems from • Various vendors • Various protocols (Fieldbus- CAN, Modbus, Flexray, etc.) • Various platforms (Windows, Linux, VxWorks, proprietary,…) • Connect to MES, ERP and higher levels of the Factory Automation • Connect to cloud • Still retain its real time characteristics.	• EPICS is designed to be used for integrating heterogeneous systems. • EPICS based gateways can be easily programmed/configured to support various protocols and connect to various Fieldbuses • EPICS, being based on the regular TCP/IP based stack, can integrate very well with the ERP and MES systems and can also facilitate connectivity to cloud. • EPICS has good soft real time characteristics • EPICS being based on TCP/IP can run on Wired Ethernet or Wireless (Wi-Fi). So it is in line with the trend of Ethernet based protocols.
2	Scalable – • Ipv6, 6LowPAN, Zigbee to connect more devices • Big Data	• EPICS can be used to connect to various protocols • EPICS can facilitate for local storage on the edge of the network

Characteristics of IoT and applicability of EPICS

Sr.No.	Required Characteristics of Industrial Automation/IoT	Advantages of EPICS
3	Programmable • The systems need to be centrally programmable/configurable. Each node, even the boundary node needs to be centrally programmable. • Reduce application engineering time • For this provide facilities to quickly integrate/develop new applications • Also provide facilities to develop distributed applications • Reduce process control configuration • Provide facility for network wide system configuration, software updates, remote configuration etc.	• EPICS provides the graphical programming facility • It also provides the facility to download configuration, such that program behavior can be changed at run time. • Application development framework is provided by EPICS

4	Device to Device
	• More device to device communication, since devices will be more intelligent
	• Types of communication
	  • Product to Robot
	  • Robot to Robot
	  • Robot to back-end(server)
		• EPICS used channel Access and pVAccess (EPICS 4), both of which are subscribe-publish kind of protocols and both are suitable for device to device communication.

5	Intelligent/Autonomous systems/Products – • Systems need to take more decisions on their own, also in cases when network connectivity is not available.	• EPICS real time database provides facility to program edge devices such that they can take autonomous decisions

Characteristics of IoT and applicability of EPICS

Sr.No.	Required Characteristics of Industrial Automation/IoT	Advantages of EPICS
6	Visualization tools • Need good and simple visualization tools	• EPICS provides good visualization tools
7	The systems are most likely to be event based and data centric.	• EPICS is ideal for event based systems and data centric systems.
8	Standards conformance • Support for standard interfaces • IEC61499	• Currently there are many competing standards • EPICS can be adopted for IEC 61499 or other conformance
9	Safety and data security • Encryption,VPN,Secure authentication	• VPN can be integrated, encryption and authentication needs be buikt into.
10	• Service based	EPICS 4 supports pvAceess which has support for SOA
11	• Semantics	• EPICS being based on standard TCP/IP stack, can be easily integrated into semantic based solutions, which will be required for autonomous products.

Probable Usage scenarios in Industrial Automation

Current Usage Scenarios

Mostly in scientific Experiments like-

- ITER (France)
- NCRA – Radio Telescope (Pune, India)

…….

Probable Usage Scenarios in Industrial Automation

- Industrial Automation –
  - Edge Control Node
  - Smart Product
  - Supply Chain management – Track and Trace
  - Robots
  - Automatic Guided Vehicles
  - Fab – Control Node connecting hard real time field buses to rest of the system
- Building Automation
  - Control Node
- Home Automation
- Environment monitoring
- Locomotive domain –
  - Control node
  - HMI node

Challenges and Conclusion

Challenges

- As mentioned above, EPICS has most of the characteristics as required for new IoT requirements. However these need to be further enhanced to make EPICS ideal for IoT applications. Specifically-
  - The required drivers, device interfaces required for common IoT devices, protocols need to be developed.
  - EPICS needs to inherently support security
  - Standards conformance needs to be developed

Conclusion

- Overall, with the above considerations, EPICS could be a major middleware used in new industrial automation and IoT systems. The following additional features make EPICS a very competitive option for IoT
  - EPICS is vendor neutral
  - EPICS eco-system provides several such tools, which are not provided by other middleware solutions
  - EPICS real time database is suitable for real time processing at the boundary/edge and EPICS support central programming and configuration are very suitable for emerging IoT requirements.

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Thank You

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