The Strange Physical World of Industrial Ethernet

Mike Nager, METZ CONNECT USA Inc.
What is Industrial Ethernet?

- It’s a specific type of “Internet of Things” used to describe Ethernet used on manufacturing plant floors or in process facilities.

- It is rapidly growing already. 23% of the 31.3 million industrial networked nodes in 2011 were based on Ethernet. – IMS Research

- Total economic value of IoT will be $1.9T by 2020 with manufacturing and health care verticals leading at 15% each. – Gartner Inc.
What is Industrial Ethernet

M2M World of Connected Services
The Internet of Things

Devices
- HVAC, Transport, Fire & Safety, Lighting, Security, Access, etc.
- Office, Education, Retail, Hospitality, Airports, Stadiums

Locations
- Servers, Storage, PCs, Routers, Switches, PBXs, etc.

Application Groups
- Commercial/Institutional
- Industrial
- Consumer & Home
- Energy
- Healthcare & Life Science
- Transportation

Service Sectors
- Buildings
- IT & Networks
- Security/Public Safety
- Emergency Services
- Public Infrastructure

Service Sectors
- Public
- Enterprise
- Speciality
- Retail
- Hospitality

Industry
- Telecommunications
- Oil/Gas
- Alternative
- Power
- Wind, Solar, Co-generation, Electrochemical
- Power Gen, Trans & Dist, Low Voltage, Power Quality, Energy Mgmt
- Rigs, Drills, Wells, Heads, Pumps, Pipelines
- HVAC/Climate, Lighting/Appliance, Water Treatment, Building Environ, Gen, Environ
- Security
- Sensors, E-Commerce, Data Centers, Data Collections, Mobile Carrier, Fixed Carrier, ISPs
- Human Animal, Postal, Food, Health, Packaging, Baggage, Water Treatment, Building Environ, Gen, Environ
- Surveillance
- Equipment, Personnel, Police, Fire, Regulatory
- Fuel Stations, Gaming, Bowling, Casinos, Discos, Special Events
- POS Terminals
- Cash Registers
- Vending Machines
- Signs, etc.

Healthcare & Life Science
- In-Home/Office, Research, Hospital, EDC, Home, Lab, Doctor Office, Hospital, EDC
- Hospital, EDC, Mobile, Lab, Doctor Office, Hospital, EDC
- MRL, PDMs, Implants, Home, Monitoring Systems
- Diagnostics, Lab, Telematics, etc.

Transportation
- Pumps, Valves, Vats, Conveyors, Pipelines
- Motors, Drives, Converting, Fabrication
- Assembly/Packaging, Vessels/Tanks, etc.

Industrial
- Industrial
- Manufacturing
- Automation, Robotics
- Medical, Paper, Wood, Agriculture, Food, Chemicals, Fuels, Textiles, Rubber, Plastics

Consumer & Home
- In-Home, Entertainment, Convenience & Entertainment
- Care, In-Home, Home, Lighting, Automation, Assisted Living
- Hospital, EDC, Mobile, Lab, Doctor Office, Hospital, EDC
- MRL, PDMs, Implants, Home, Monitoring Systems
- Diagnostics, Lab, Telematics, etc.

Energy
- Supply/Demand
- Alternative
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- Power Gen, Trans & Dist, Low Voltage, Power Quality, Energy Mgmt
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Infrastructure
- Digital Cameras, Power Systems, MDI, Dishwashers, refrigerators, Desktop Computers, Power Systems, MDC
- Security/Accrual, Fire/Safety, Environ, Safety, Children, Power Protection
- Washers/Dryers, Electronics, Monitors, DVD, CD, TV, MPR, Games Consoles, Lighting
- Alarms, etc.

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What is Industrial Ethernet

- Industrial
  - Resource Automation
  - Fluid/Processes
  - Converting/Discrete
  - Distribution
  - Mining, Irrigation, Agricultural, Woodland
  - Petro-Chem., Hydro, Carbons, Food/Bevage
  - Rubber/Plastic, Metalworking, Electronics
  - Materials Handling, Conveyance
  - Pumps, Valves, Vats, Conveyors, Pipelines
  - Motors, Drives, Converting, Fabrication
  - Assembly/Packaging, Vessels/Tanks, etc.
The Internet of Things

Industrial Ethernet Accounts for the Biggest Growth

The Internet of Things

The Industrialization of the Internet … Internet of Things

- 2007: Total 500 Million, 1/10th of a Device per Person on Earth
- 2010: Total 35 Billion, 5 Devices per Person on Earth
- 2013: Total 1 Trillion, 140 Devices per Person on Earth

1997–2001: business the net
2003–2009: consumer social media web 2.0
2010–2013: industrial internet of things web 3.0

Source: Forester Research, CISCO
“Industrial” Looks Different

- Ethernet is the biggest thing to hit manufacturing facilities but it’s a lot different then the typical Enterprise network.

- According to IMS Research only about 40% of installed industrial Ethernet nodes are standard TCP/IP and seems to be decreasing slightly over time.
A Look at the Past

- Islands of Automation
  Machines were self contained entities with little communication between each other or the plant facility. Relay logic prevailed.
A Look at the Past

Islands of Automation

Relays were replaced by PLCs and remained ‘stand-alone’. Some specialized networks started to replace the direct wiring but control and information remained locked to that machine.

http://www.flickr.com/photos/92287895@N00/267323861/in/p hotolist-pC756-3RpqjT-4b86wT-4bc7HW-4bc7NQ-73JDy1- eoYJAp-fySBbZ-aTkNbV-aTkLQ2-aTkP8P-a3Qx5T-bjcrXK- aTkxyg-aTkeA6-faqaCM-faqaVz-cLL5F3-awSD60-dzbGD5- b1XcEn-8dkSKQ-bie2Q4-bidUjp-a17jSR-a17iPX-a1abCo- a17jki-a1aaRf-a17jbZ-a1ab2J-a17j8x-a1aaLd-a17jxn-a1abej- a17jAp-9ZNoSk-9ZRf8W-a1ab3J-a1aaFW-ftTdsT-a1ab4Y- a17j2X-a17jRi-a17jrf-a17jEK-a17jqB-a17jHD-a17jmn-a17jS4- a1abib
Ethernet to the Rescue

Islands of Automation

Ethernet was seen as method of extracting information from the PLC and maybe even its I/O so at least reports could be made.

ETHERNET

GW

Discrete Control

GW

DeviceNet

GW

Profibus

GW

SERCOS
But Why Not All the Way?

If machines were connected via Ethernet, why couldn't they be CONTROLLED by Ethernet? Little by little, the objections were overcome.

- Ethernet isn’t Fast Enough – We need ‘Real Time Controls’
- Ethernet isn’t Deterministic – We can’t have jitter
- Ethernet Topography isn’t suitable – Star won’t work
- Ethernet isn’t redundant – Can’t have single Source of failure
- Ethernet Components aren’t designed for industry – this presentation!
Progression

But Why Not All the Way?

If machines were connected via Ethernet, why couldn't they be CONTROLLED by a variant Ethernet?
Seemless Infrastructure

Building Network
Data Center
Industrial Ethernet
ERP
MES
Supervisor
Machine
DCS/PLCs/IPCs
Device
Sensors/Actors

Transparent Communication over all business levels without Interfaces and communication losses

use of common IT processes for operation and observation via web technology

Web server on PLCs and machines, remote maintenance and teleservice directly from the network

Easy installation and operation with convergent using
The Buzz Now

Trade Publication

Industrial Ethernet is discussed ALL THE TIME
Outlook

Outlook of Industrial Ethernet
Recent poll from Automation World

What Is your Opinion of Ethernet Use in Industrial Plants?

- 49% Ethernet will eventually replace legacy fieldbus networks in our operations.
- 47% Ethernet and legacy fieldbus protocols will continue to evolve side by side, as they address different industrial network needs.
- 4% Fieldbus will continue to be our preferred industrial network technology, with Ethernet used in limited application.

Source: Automation World Nov. 2013 Fieldbus survey, 466 responses

In the Past Five Years Have You...

- 70% Installed FIELDBUS systems/devices
- 86% Installed ETHERNET systems/devices
- 66% Installed both FIELDBUS and ETHERNET
- 4% Installed FIELDBUS but not ETHERNET
- 21% Installed ETHERNET but not FIELDBUS
- 9% Installed neither FIELDBUS nor ETHERNET

Source: Automation World Nov. 2013 Fieldbus survey, 463 responses
You Aren’t in Kansas Anymore

- Users familiar with NEMA / IP ratings and rather than MICE. (Mostly Mice 2 and 3 areas)
- DIN rail mounted devices not 19” Racks
- Supply voltage is 24VDC not -48V
- Classified hazardous areas exist (Division 1 and 2)
- No Plenum/Riser Cables – Oil Resistant or High Flex
IP Environmental Ratings

<table>
<thead>
<tr>
<th>Classes</th>
<th>M_1</th>
<th>M_2</th>
<th>M_3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mechanical Rating</td>
<td>I_1</td>
<td>I_2</td>
<td>I_3</td>
</tr>
<tr>
<td>Ingress Rating</td>
<td>C_1</td>
<td>C_2</td>
<td>C_3</td>
</tr>
<tr>
<td>Climatic Rating</td>
<td>E_1</td>
<td>E_2</td>
<td>E_3</td>
</tr>
<tr>
<td>Electromagnetic Rating</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
IP Environmental Ratings

- IP20 for components inside control cabinets
- IP65/67 for components outside control cabinets

### Table: IP Environmental Ratings

<table>
<thead>
<tr>
<th>First Number</th>
<th>Definition</th>
<th>Second Number</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>No protection</td>
<td>0</td>
<td>No protection</td>
</tr>
<tr>
<td>1</td>
<td>Protected against solid objects over 50mm (e.g. accidental touch by hands)</td>
<td>1</td>
<td>Protected against vertically falling drops of water</td>
</tr>
<tr>
<td>2</td>
<td>Protected against solid objects over 12mm (e.g. fingers)</td>
<td>2</td>
<td>Protected against direct sprays up to 15° from the vertical</td>
</tr>
<tr>
<td>3</td>
<td>Protected against solid objects over 2.5mm (e.g. tools and wires)</td>
<td>3</td>
<td>Protected against direct sprays up to 60° from the vertical</td>
</tr>
<tr>
<td>4</td>
<td>Protected against solid objects over 1mm (e.g. tools, wires and small wires)</td>
<td>4</td>
<td>Protected against sprays from all directions - limited ingress permitted</td>
</tr>
<tr>
<td>5</td>
<td>Protected against dust - limited ingress (no harmful deposit)</td>
<td>5</td>
<td>Protected against low pressure jets if water from all directions - limited ingress permitted</td>
</tr>
<tr>
<td>6</td>
<td>Totally protected against dust</td>
<td>6</td>
<td>Protected against strong jets of water e.g. for use on shipdecks - limited ingress permitted</td>
</tr>
<tr>
<td></td>
<td></td>
<td>7</td>
<td>Protected against the effects of temporary immersion between 15cm and 1m. Duration of test 30 min.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>8</td>
<td>Protected against long periods of immersion under pressure</td>
</tr>
</tbody>
</table>
General “Industrial” Requirements

Industrial locations include the manufacturing floor, process plant, traffic control, water treatment, and transit systems needing:

- “Real Time” Control Needs
- Multiple levels of redundancy
- More extreme vibration and shock
- Water, Dust, Coolant Exposure
Industrial Device Connections

- Industry field plug
  - Cu IP20

- Industry V1 plug

- Industry V4 plug

- M12 plug
  - X-coded IP67

- M12 plug
  - D-coded IP67

- M12 LP-socket
  - X-coded IP67

- Industry V1 plug

- Gigabit-terminal block
  - IP20

- RJ 45 LP-jack
  - IP20
# Industrial Bus Networks

<table>
<thead>
<tr>
<th>Network</th>
<th>Founder</th>
<th>Organization</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ethernet/IP</td>
<td>Rockwell Automation</td>
<td>ODVA</td>
</tr>
<tr>
<td>Profinet</td>
<td>Siemens</td>
<td>PTO</td>
</tr>
<tr>
<td>MODBUS-TCP</td>
<td>Schneider Electric</td>
<td>Modbus IDA</td>
</tr>
<tr>
<td>Foundation Fieldbus</td>
<td>Fieldbus Foundation</td>
<td>Fieldbus Foundation</td>
</tr>
<tr>
<td>SERCOS</td>
<td>Bosch Rextroth</td>
<td>Interest Group Sercos</td>
</tr>
<tr>
<td>EtherCAT</td>
<td>Beckhoff Automation</td>
<td>EtherCAT Technology Group</td>
</tr>
</tbody>
</table>
Cable Recommendations

- Profinet recommends Shielded Cables
- Ethernet/IP prefers unshielded systems
  - But Recommends shielding for
    - Induction welding processes
    - RF Sources
    - Electrostatic processes
    - High current devices (more than 100 amps)
- Uses shields with RC network to prevent DC ground loops
Physical Layer Issues

- According to an ISA.org online article, Physical Layer failures accounted for 35% of total failures in plant automation.
- Two ways to provide reliability is to:
  - Harden the physical layer
  - Change the network topography
Connector Recommendation

- Industrial Control Manufacturers

Guidelines are given by the manufacturers, in this case for EtherNet/IP systems.

**IP65/IP67 sealed connectors**

If your application exposes cable and connectors to liquid, dust or airborne contaminants as described in the MICE table (*Table 5.1 on page 5.72*), use the appropriately rated connector. IP65/IP67 sealed connectors and bulkhead feed-throughs should be utilized. See *Chapter 2.*

**Important:** Not all connectors are suitable for harsh environments. Carefully select connectors for the intended environment. Only consider connectors recognized by the ODVA Industrial EtherNet/IP specification.
First Step – Harden RJ45

Nylon Locking Tab and Strain Relief

Need to accommodate large individual conductors

Metal Die Cast Housing
Second Step – Harden Some More

- **Rugged Construction**
  Here is a metal version of the “V1” connector system.

- Threads and Gaskets for Sealing
  - Cable Glands and Stress Relief
Second Step – Harden Some More

Rugged Construction

Here is a metal version of the “V14” connector system.

Snap on connector
Second Step – Harden Some More

- **Rugged Construction**
  
  A custom built connector that is explosion proof for the Oil and Gas industry.
Third Step – Engineer New System

- High Band Width Connectors – M12 Footprint
- “D” Code for 2 Twisted Pairs
- “X” Code for 4 Twisted Pairs
Cutting Edge Standard

- X Code M12 for Industrial Gigabit Speeds

Typically PUR or PVC Cable

4 Shielded Pairs in an X shape
IP67 Ethernet Switch

› Electronics

Not only connectors need to be rugged.

Metal Housing

M12 Connectors
Conversion from RJ45 to M12

<table>
<thead>
<tr>
<th>M12</th>
<th>RJ45</th>
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<tbody>
<tr>
<td>1</td>
<td>OG-WH</td>
</tr>
<tr>
<td>2</td>
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</tr>
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<td>3</td>
<td>GN-WH</td>
</tr>
<tr>
<td>4</td>
<td>GN</td>
</tr>
<tr>
<td>5</td>
<td>BU-WH</td>
</tr>
<tr>
<td>6</td>
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Inside the Cabinet – DIN Rail
Inside the Cabinet – DIN Rail

- RJ45 Jack Meets DIN Rail

DIN Rail is the defacto mounting method on the plant floor so devices and connectors are needed in this form factor.
Inside the Cabinet – DIN Rail

- Fiber Optic Meets DIN Rail
Reliable Extensions and Repairs

Practicality

Repairs and Extensions to Ethernet cable need to be done on the plant floor – they will not re-run wires through plants or machines with moving parts unless absolutely necessary. Think of it as a type of consolidation point.
Key Take-Aways

- Internet of Things is growing rapidly
- Much of it is in the industrial sector – Industrial Ethernet
- Environmental considerations are much different than office environments
- Physical component failure is the single biggest failure point so the physical layer components have to be well considered
The Strange Physical World of Industrial Ethernet

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Connect with us!