

Substation Communications Design - Legacy to IEC 61850

Best Practices

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Chris Jenkins

Overview

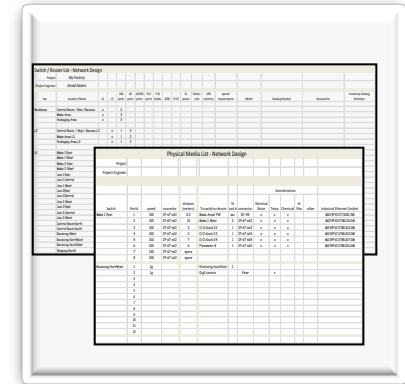
- This presentation is Part 1 of 3 of our series:
Substation Communications Design, Legacy to IEC 61850
- At the end of this presentation you should take away AT LEAST ONE new idea that you can use on current projects
- Additional resources are provided at the end

Let's get started!

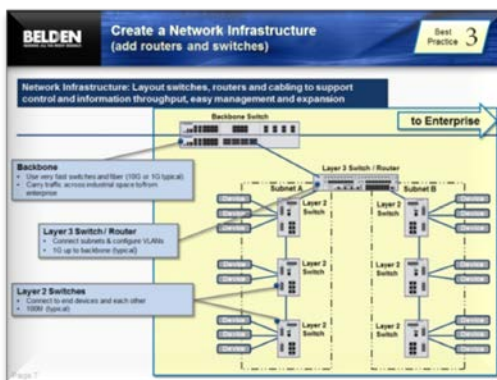
Introduction

Belden's Substation Communications Infrastructure design overview enables you to compare your designs to industry best-practices.

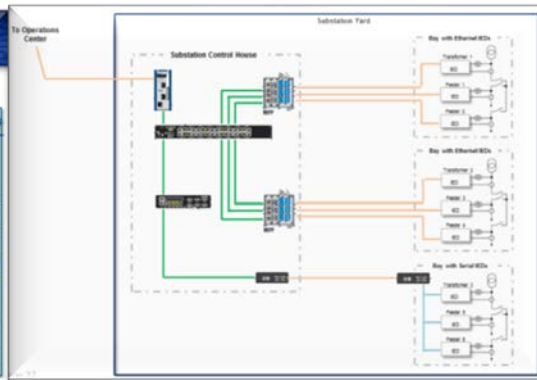
- 10 easy steps
- Provides you with insight & ideas for improvement
- Helps us better understand your needs
- The things we'll use are:



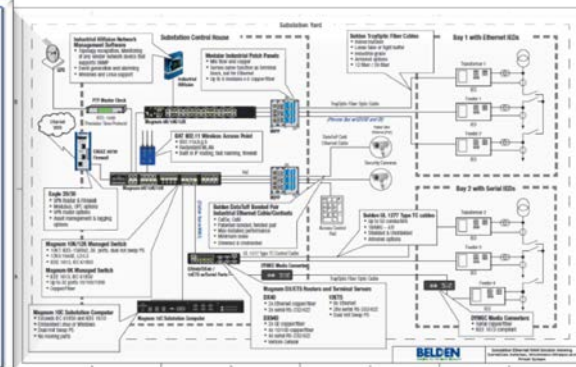
Excel Worksheets



Best Practices



Examples



Popular Configuration Drawings



Product Guides

Segment Ethernet communications into groups (subnets)

Best Practice **1**

Subnet: As your Ethernet network grows, break a large network into smaller ones connected by routers or layer 3 switches

Layer 3 Switch / Router

- Connects subnets
- limits data in and out of each subnet
- provides security

Rule of thumb

80% traffic stays in subnet
20% traffic travels in/out

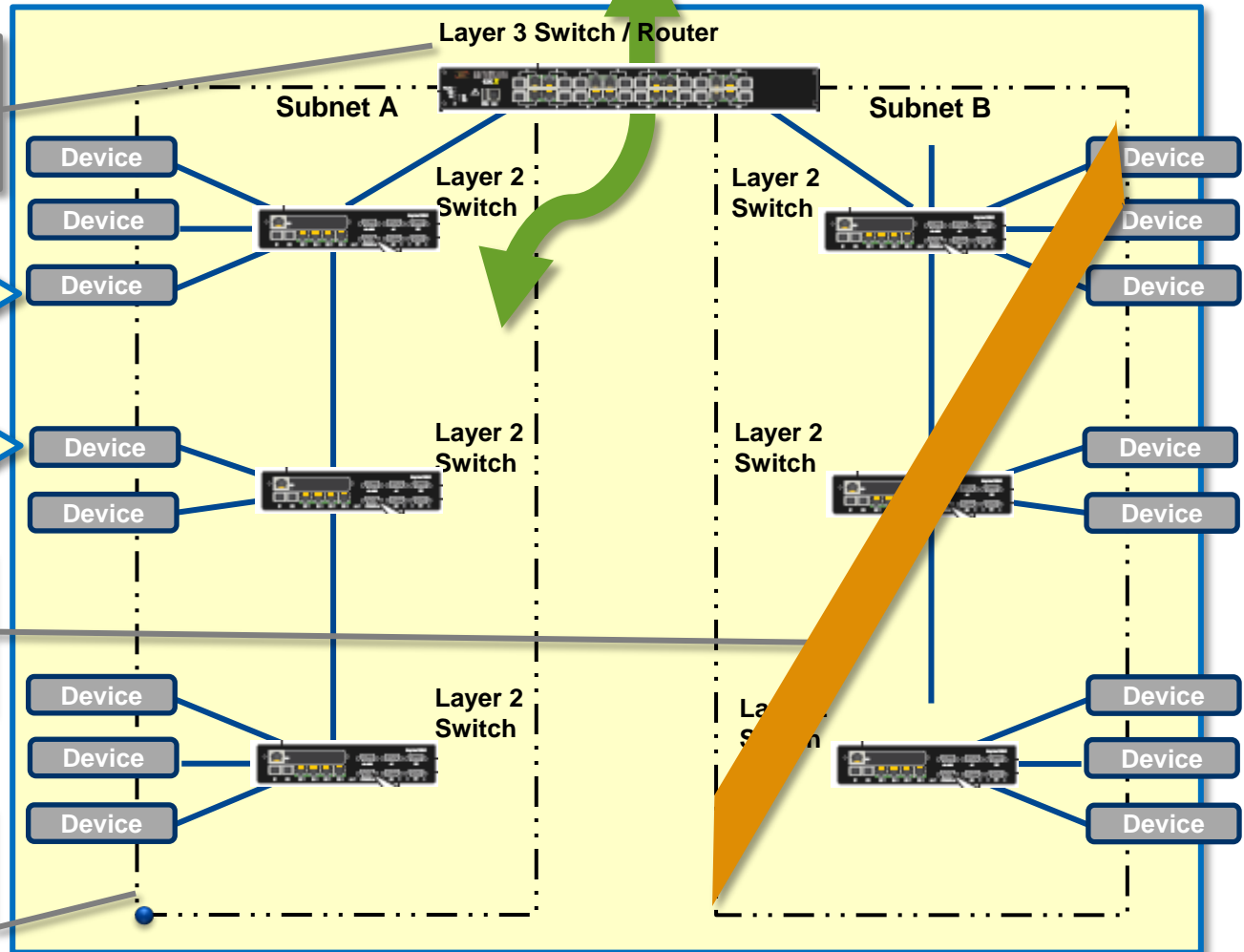
Devices on the same subnet easily talk

Reliability, Management, Maintenance

One subnet can be stopped without affecting others

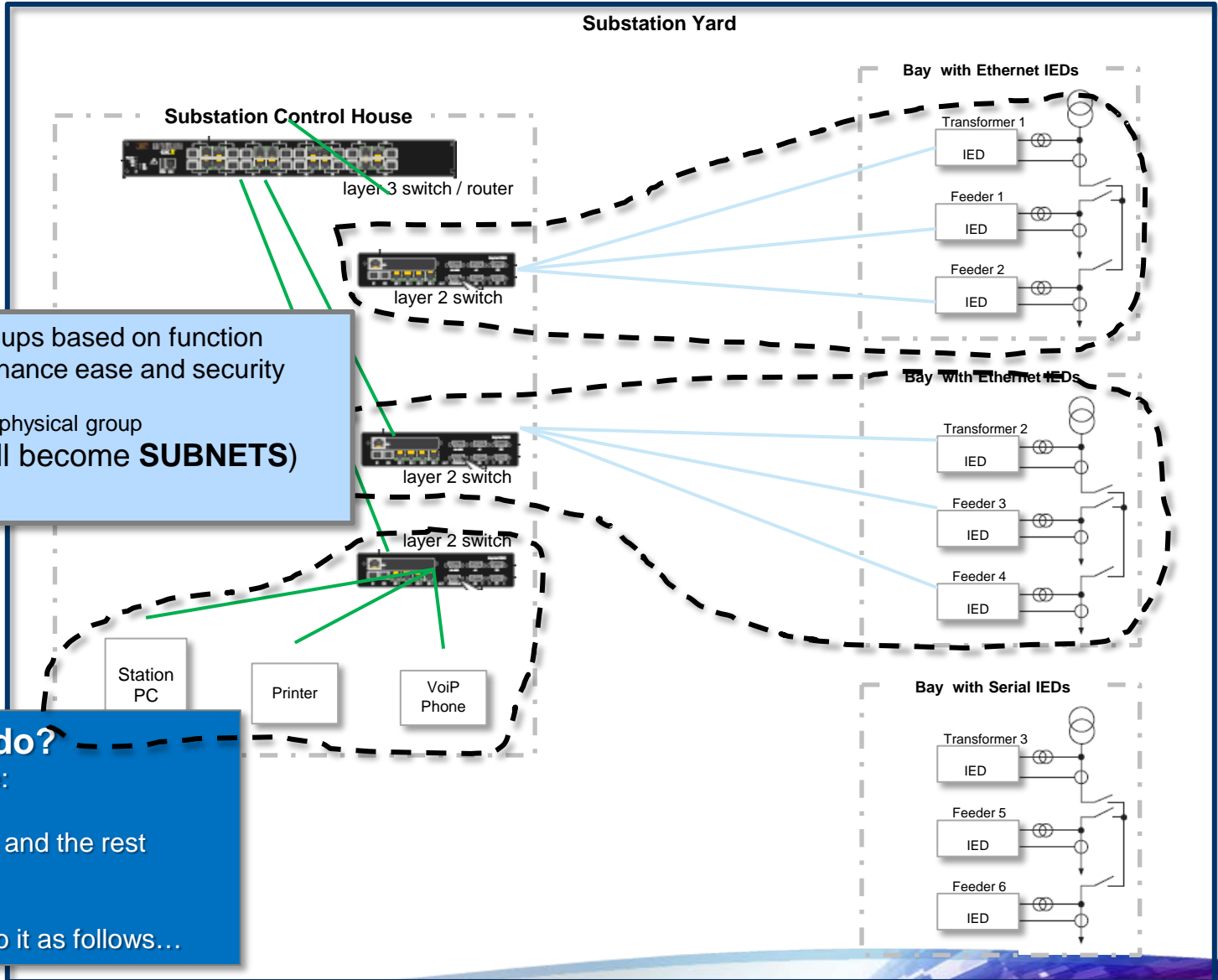
Subnets are great for isolating:

- High performance
- High bandwidth traffic (video, voice)



Segment communications into groups (subnets)

Example 1



A – Create physical groups based on function and location for maintenance ease and security

Devices in a physical group (these will become **SUBNETS**)

What would you do?
This application could be:

- 1 subnet
- 2 subnets – process and the rest
- Several subnets

For this example, we'll do it as follows...

Record Your Infrastructure Choices

Record Your Choices **1**



Switch / Router List - Network Design

Project	<i>Deb-Bay Substations 20-31</i>									
Project Engineer	<i>Andrew T.</i>									
		External	Ethernet							
Use	Location /Name	Secure External Comms	L3 / Router	L2	10G ports	1G ports	10/100 ports	PoE ports	PoE+ ports	1588 precision time
External comm	Router 20	WAN	x			1	3			
Bay 1	Switch B1			x			6			
Bay 2	Switch B2			x			6			
Control House	Switch CH Equip 3			x			8			

Segment Communications into Groups (vLANs – Virtual LANs)

Best Practice **2**

VLAN: Create LOGICAL groups of Ethernet devices that cannot be easily physically grouped

Layer 3 Switch / Router are used

- To configure VLANs
- Limits data in/out of VLAN
- Provides security to VLAN

Rule of thumb

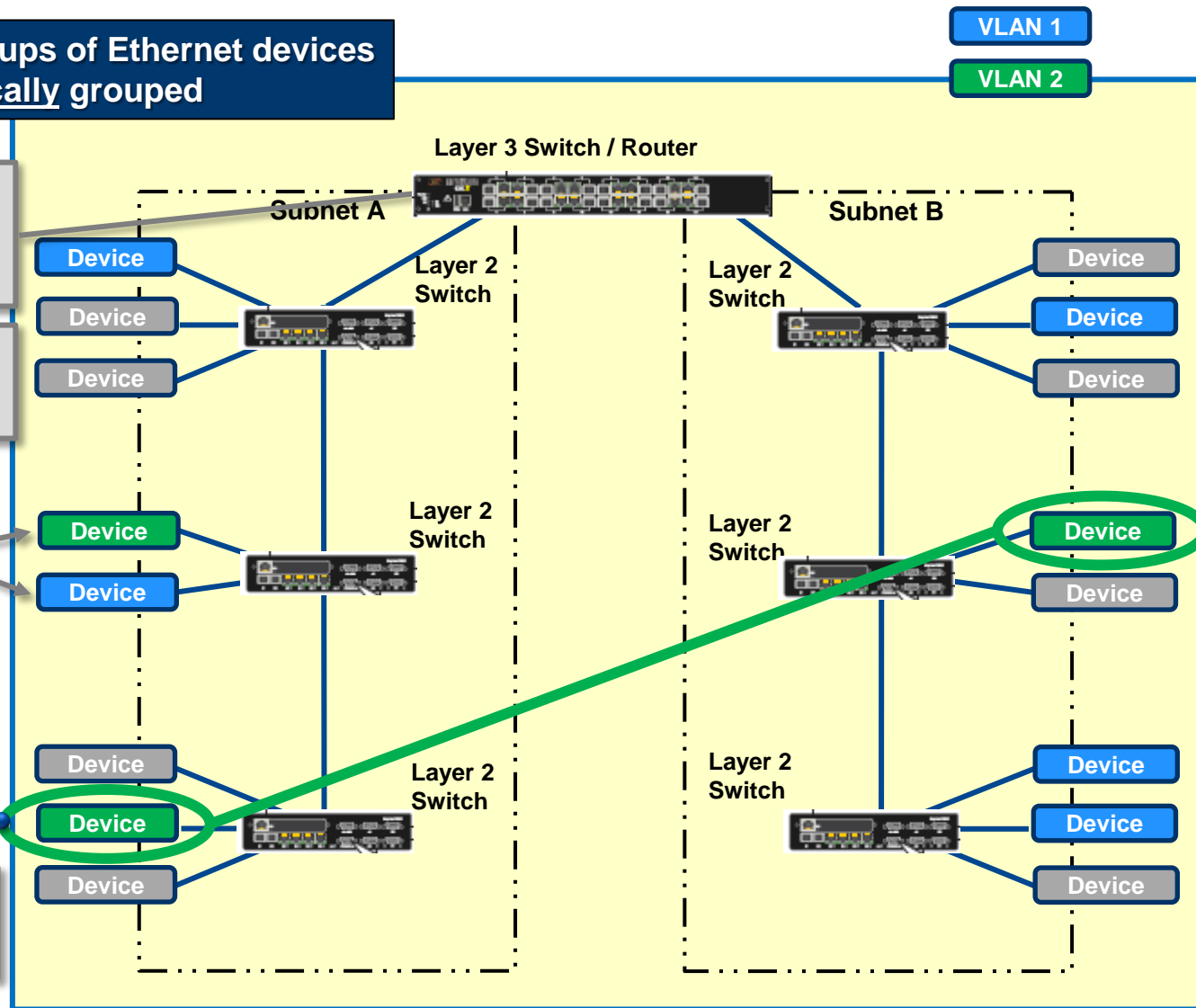
80% traffic stays in VLAN
20% traffic travels in/out

OK for devices from multiple VLANs to connect to a switch

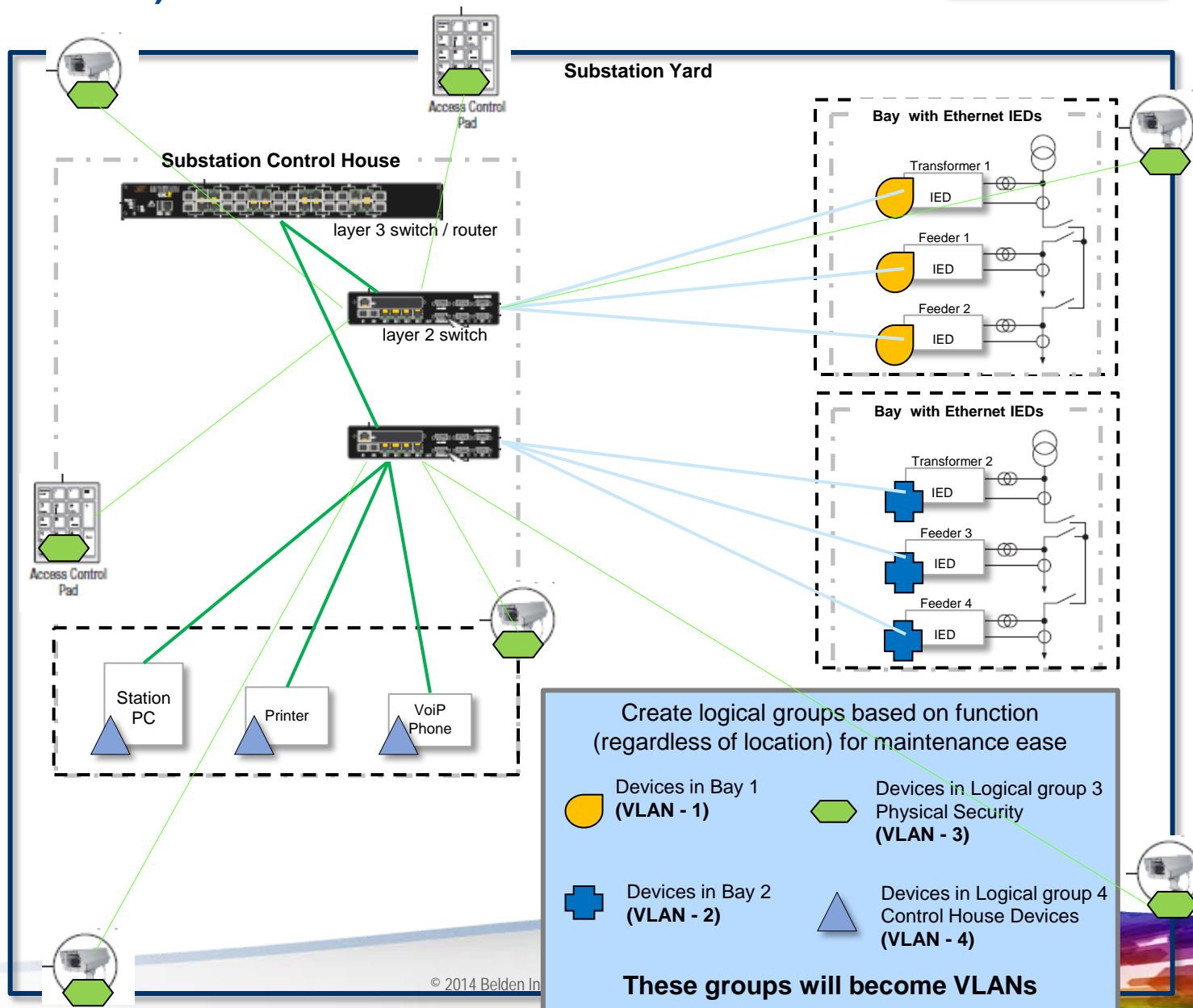
Devices in the same VLAN can easily talk

VLANs are great for isolating

- High bandwidth traffic (video, voice)
- Distributed groups of data



Segment Ethernet Communications into Groups (vLANs – Virtual LANs)



Add Serial Communications Devices to your Ethernet Infrastructure

Best Practice **3**

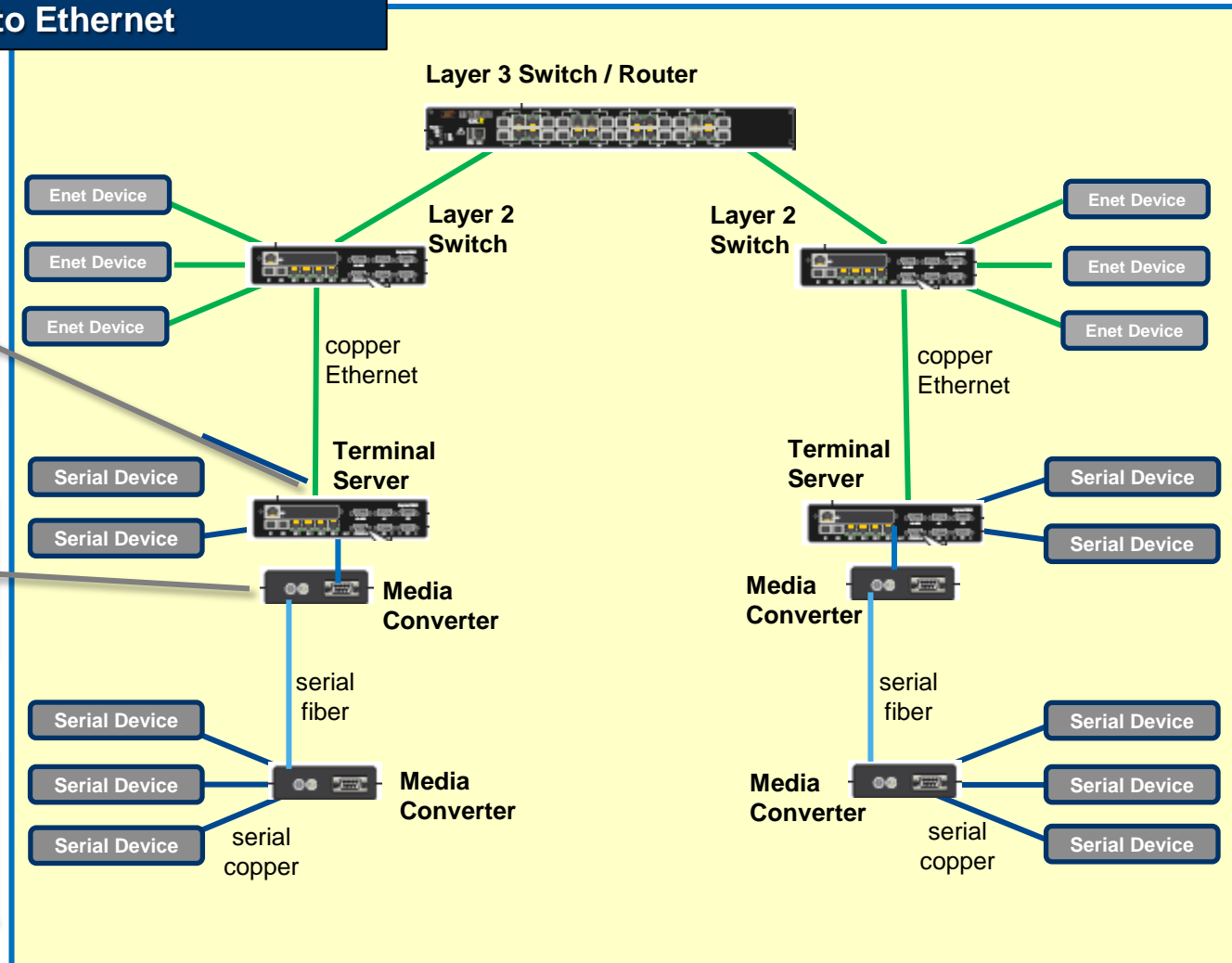
Connect to Legacy IEDs and other Serial Communications Devices to Ethernet

Terminal Servers connect multiple serial devices to Ethernet (and the rest of the infrastructure)

Use media converters to change copper serial signals to fiber in high electro-mechanical noise areas

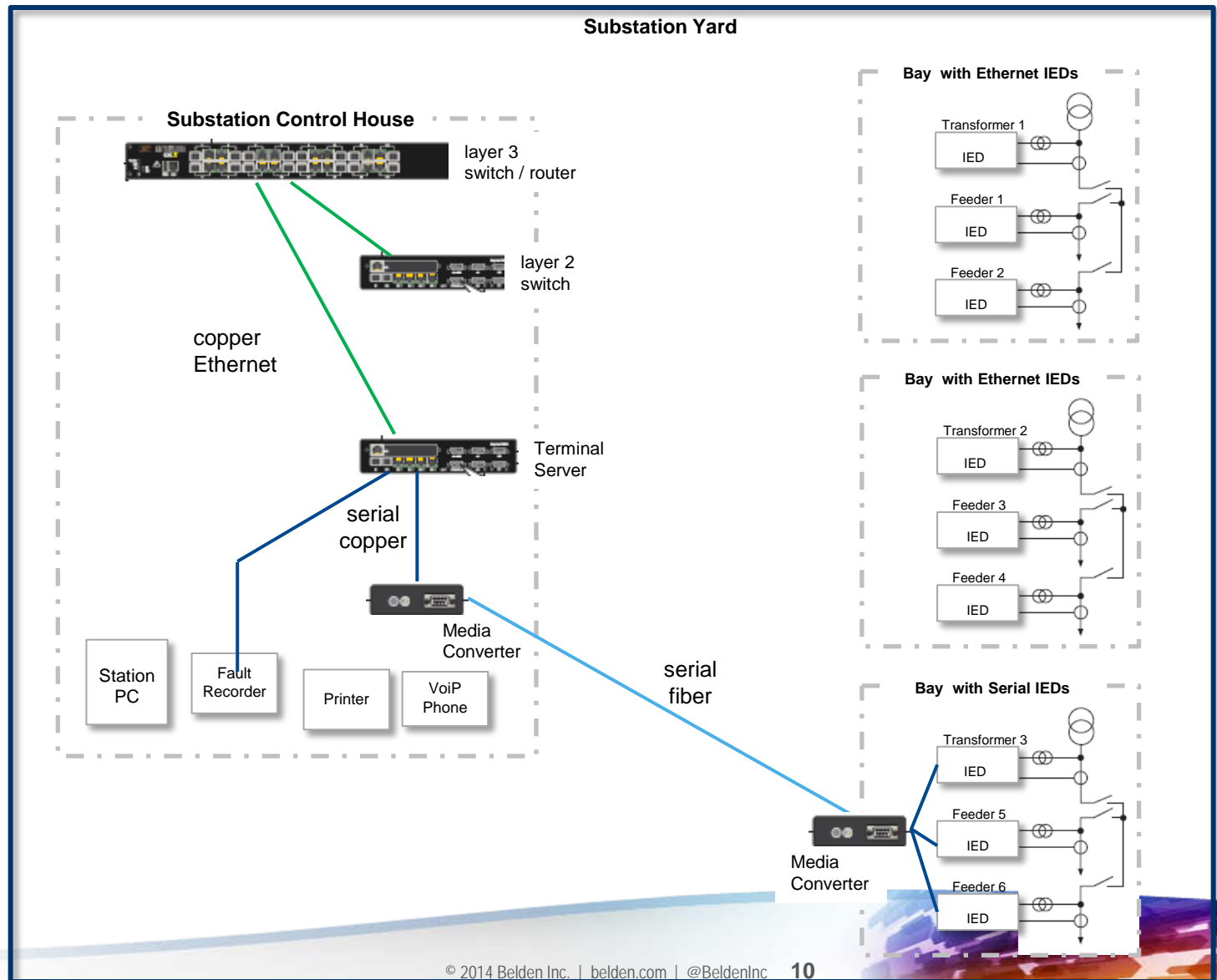
Adding Serial Devices to an Ethernet Infrastructure provides:

- Continued use of serial devices
- Upgrade of their overall communications



Add Serial Communications Devices to your Ethernet Infrastructure

Example 3



Record Your Serial Choices

Record Your Choices **3**



Switch / Router List - Network Design

Project	<i>Deb-Bay Substations 20-31</i>											
Project Engineer	<i>Andrew T.</i>											
		External	Ethernet								Serial	
Use	Location /Name	Secure External Comms	L3/ Router	L2	10G ports	1G ports	10/100 ports	PoE ports	PoE+ ports	1588 precision time	Serial Ports	IRIG-B precision time
External comm	Router 20	WAN	x			1	3					
Bay 1	Switch B1			x			6					
Bay 2	Switch B2			x			6					
Control House	Switch CH Equip 3			x			8					
Bay 3	Terminal Server B3										8	

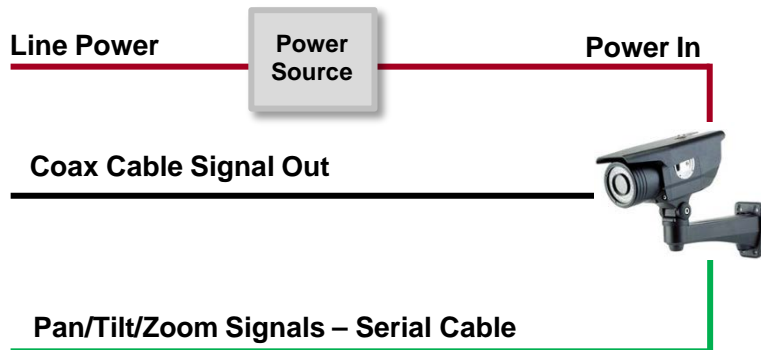


Power over Ethernet (PoE)

Best Practice **4**

Power over Ethernet (PoE) : use a single industrial Ethernet cable to provide power and Ethernet communications to devices

Traditional Approach



1. Identify PoE devices you will use (cameras, telephones, etc.) and the switch it will connect to

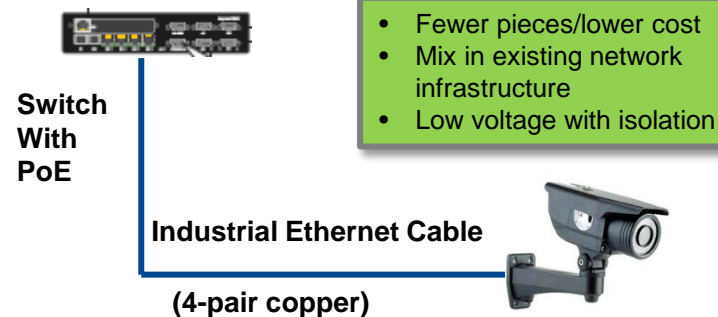
2. Identify the power consumption (in watts) of each device and total the power for all PoE devices wired to one PoE switch

- Most devices are “standard” PoE – up to 13 Watts
- Some devices are “PoE+” - up to 25.5 Watts.

Common Examples of PoE Devices




PoE Approach



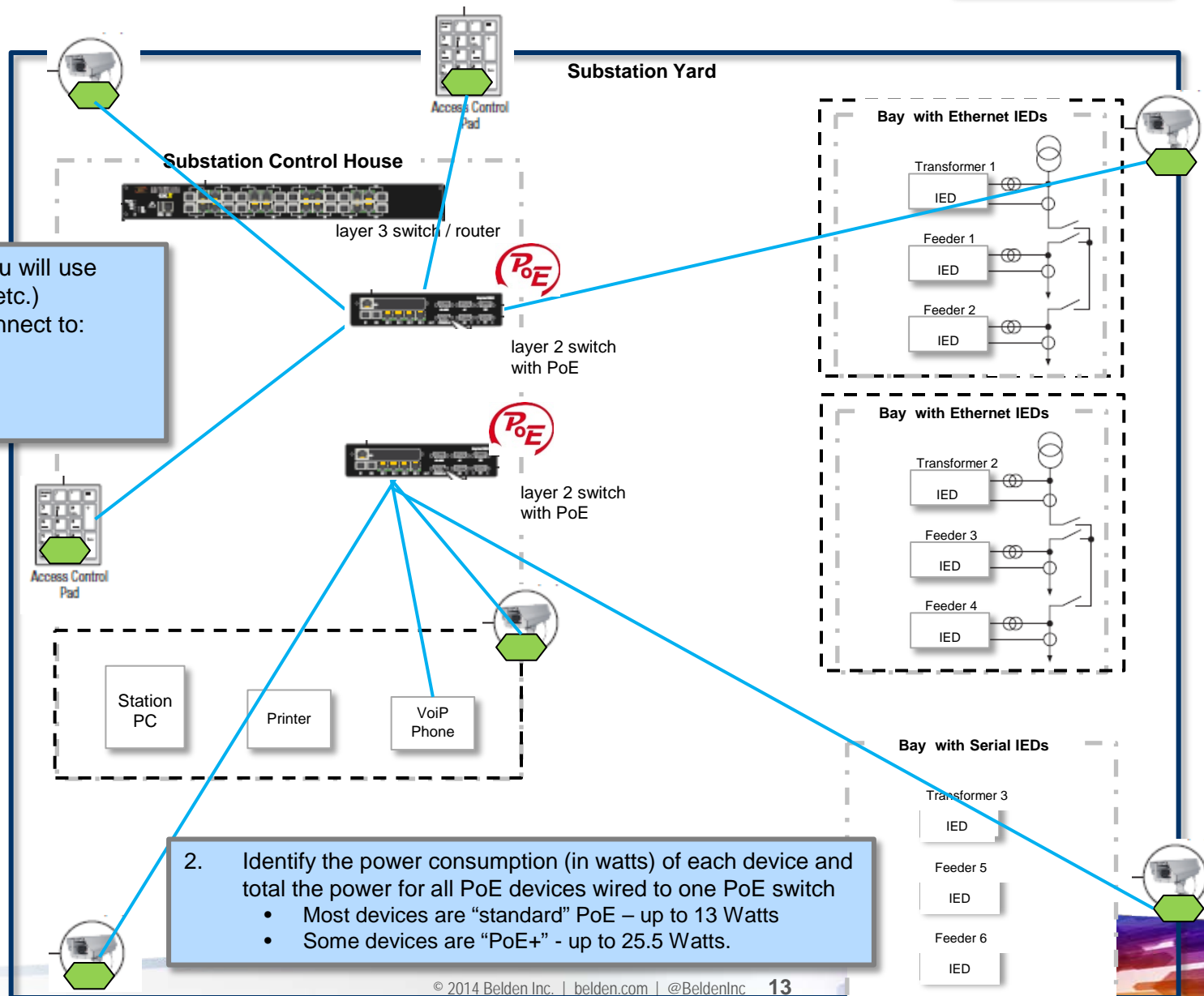
Power over Ethernet (PoE)

Example 4

1. Identify PoE devices you will use (cameras, telephones, etc.) and the switch it will connect to:

 PoE Devices

 Switches



2. Identify the power consumption (in watts) of each device and total the power for all PoE devices wired to one PoE switch

- Most devices are "standard" PoE – up to 13 Watts
- Some devices are "PoE+" - up to 25.5 Watts.

Time Synchronization

Use IEEE-1588 precision time protocol (PTP) for devices on Ethernet requiring extremely precise timing accuracy (<1 microsecond). IRIG-B is a similar, older technology



Determine if application needs sub-millisecond time accuracy

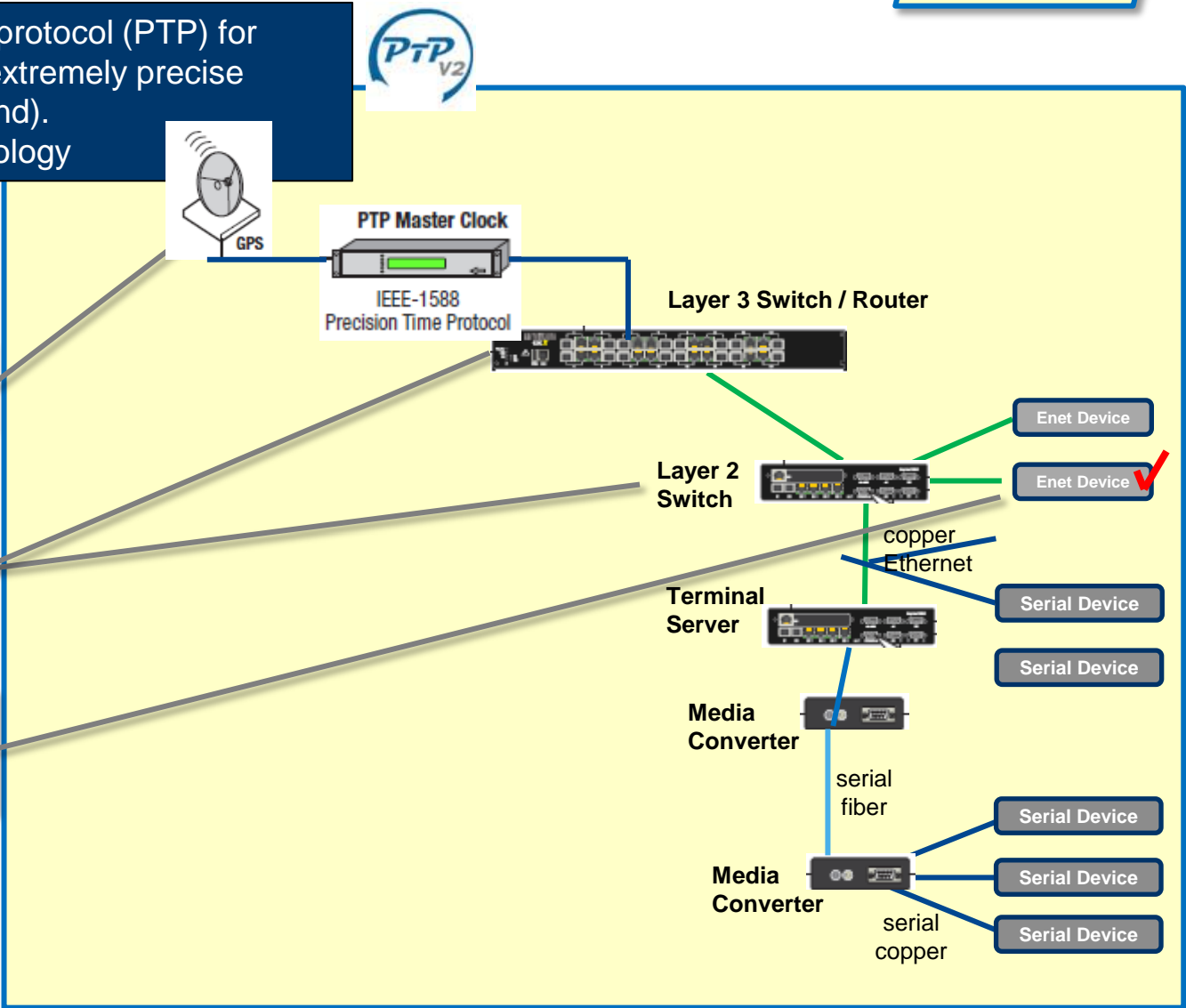
All devices synchronized to a GPS or master clock

Ensure all switches / routers / terminal servers in the path between devices needing synchronization support the technology you are using

Select devices for the application that support the technology (IEEE-1588 or IRIG-B)

Time Synchronization is ideal for:

- First fault detection
- Measurement & testing



Choose Environmental Ratings for your switches and routers

Best Practice **6**

IEC-61850 part 3 ratings describe a device's protection against environmental and other hazards

Ensure PT&D network infrastructure products are made for their environment

... and meet / exceed relevant industry standards

Consider appropriate ratings for:

- Temperature
- Humidity
- Corrosion
- Electromechanical Noise

Appropriate environmental & electrical ratings specified now eliminates trouble later !

	1/rd	Wireless	DIN Rail	Panel	19" Rack	Max Data Rate	Max Port Density	Unmanaged	Managed/Layer 3	Routing	Serial	110/230 VAC	12 VDC	24VDC	48VDC	125/250VDC	Redundant Power Inputs	PoE PSE	PoE+ PSE	Connectivity	-40°c/40°F	-25°c/13°F	75°c/167°F	85°c/185°F	UL60950	IEC 61850-3	IEEE1613	NEMA TS-2	NEBS Level 3 / ETSI	EN50155	DNV
12KX	•	•	•	•	•	G	16	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
10KT	•	•	•	•	•	G	36	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
10KG	•	•	•	•	•	G	24	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
10RX	•	•	•	•	•	G	34	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
10XTS	•	•	•	•	•	100	36	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
10ETS	•	•	•	•	•	100	36	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
10C	•	•	•	•	•	100	36	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
6K32F/FC	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
6K32T/TRC	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
6K25e	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
6K16/16V	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
6KQ/QE/8	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
6KL	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
6KM	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
4K Series	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
ES42/ESD42/IPS42	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
PES42	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
CP80	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
CSG14/14U	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
CS14	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
S14/PS14	•	•	•	•	•	100	4	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
DX1000	•	•	•	•	•	100	19	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
DX940	•	•	•	•	•	G	11	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
DX40	•	•	•	•	•	100	4	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Links	•	•	•	•	•	100	2	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Optical Stars	•	•	•	•	•	100	9	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•

Record Your Environmental & Standards Choices

Record Your Choices **6**

Project		Switch / Router List - Network Design																					
Project Engineer		Andrew T.																					
Use	Location /Name	External	Ethernet							Serial		Standards											
		Secure External Comms	L3/Router	L2	10G ports	1G ports	10/100 ports	PoE ports	PoE+ ports	1588 precision time	Serial Ports	IRIG-B precision time	Temp	Humid	Corrosion	Electro-Mechanical Noise	UL60950	IEC 61850-3	IEEE1613	NEMA TS-2	NEBS Level 3 /ETSI	EN50155	
External comm	Router 20	WAN	x			1	3			x				170F	x		x			x			
Bay 1	Switch B1			x			6			x				170F	x		x			x			
Bay 2	Switch B2			x			6			x				170F	x		x			x			
Control House	Switch CH Equip 3			x			8							170F	x								
Bay 3	Terminal Server B3										8	x		170F	x								

Add remote access & network security

Best Practice **7**

Add Remote Access & Network Security (based on risk assessment)

Add remote communications to your Layer3 Switch, Router, or Terminal Server

- Ethernet WAN
- Cellular 3G
- MPLS-PPP WAN

Ensure your remote communications device provides robust security for the edge of your substation network

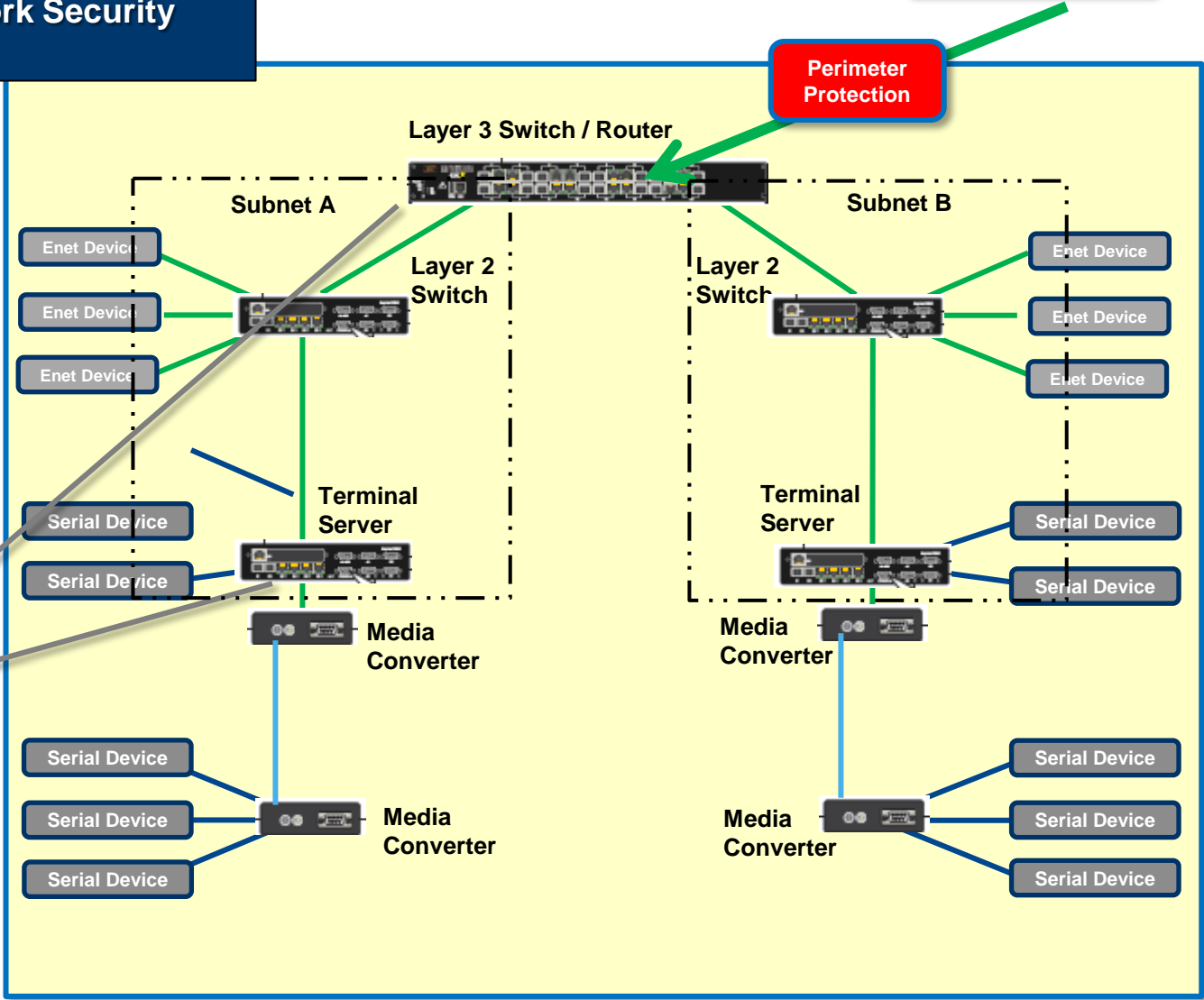
- Or add a perimeter security & communications device

Configure subnets & VLANs

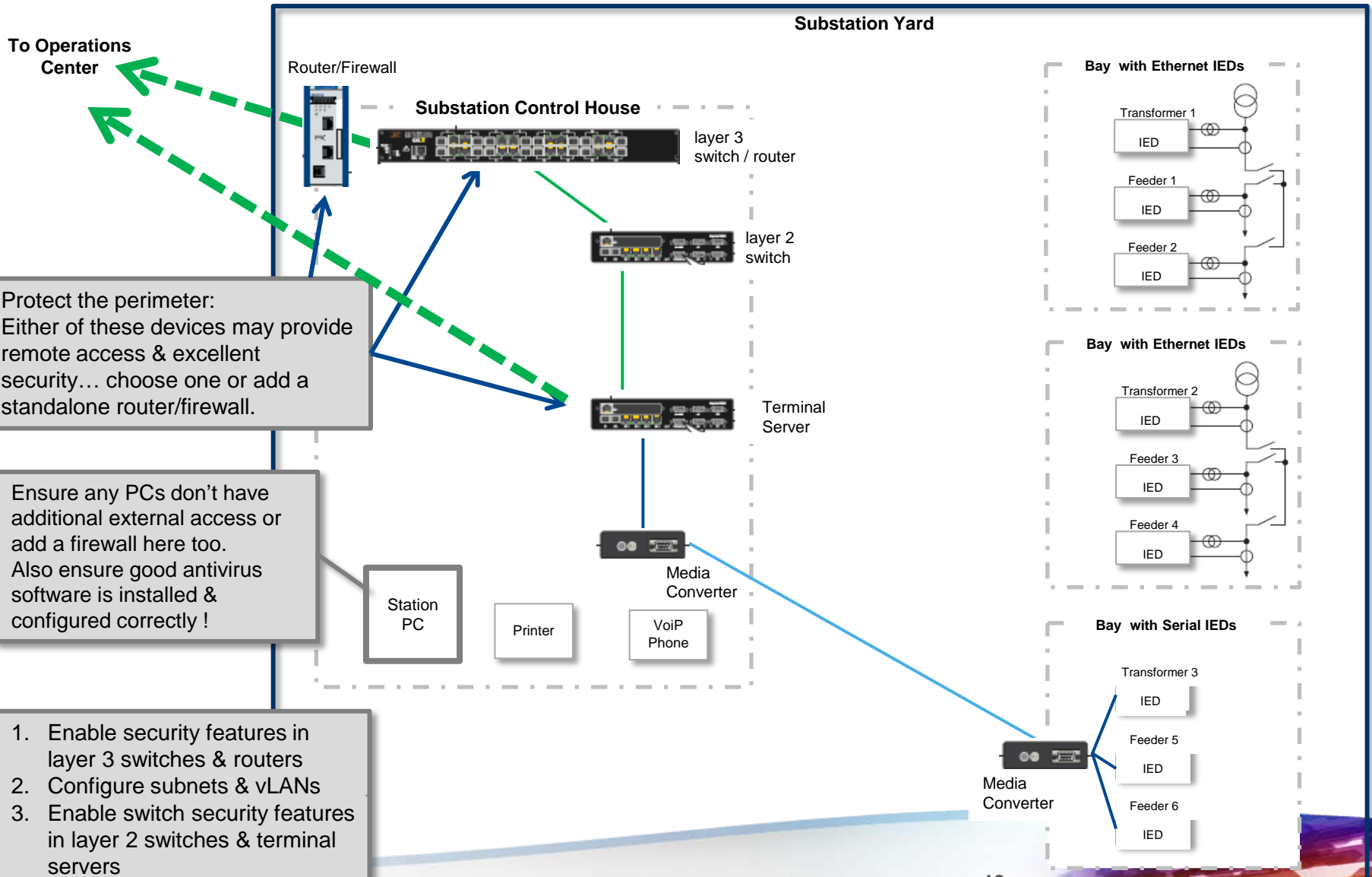
Enable security features in routers, layer 3 switches, layer 2 switches & terminal servers

Network Security is part of Defense in Depth:

- Policies & procedures
- Physical security
- Network security
- Computer security
- Device Security



Add Remote Access & Network Security



Protect the perimeter: Either of these devices may provide remote access & excellent security... choose one or add a standalone router/firewall.

Ensure any PCs don't have additional external access or add a firewall here too. Also ensure good antivirus software is installed & configured correctly !

1. Enable security features in layer 3 switches & routers
2. Configure subnets & vLANs
3. Enable switch security features in layer 2 switches & terminal servers

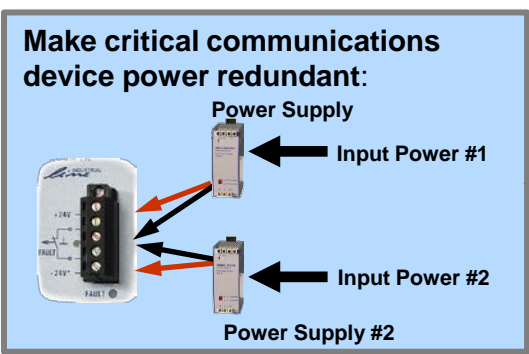
Add communications infrastructure between master & substations

Add Remote Communications Infrastructure

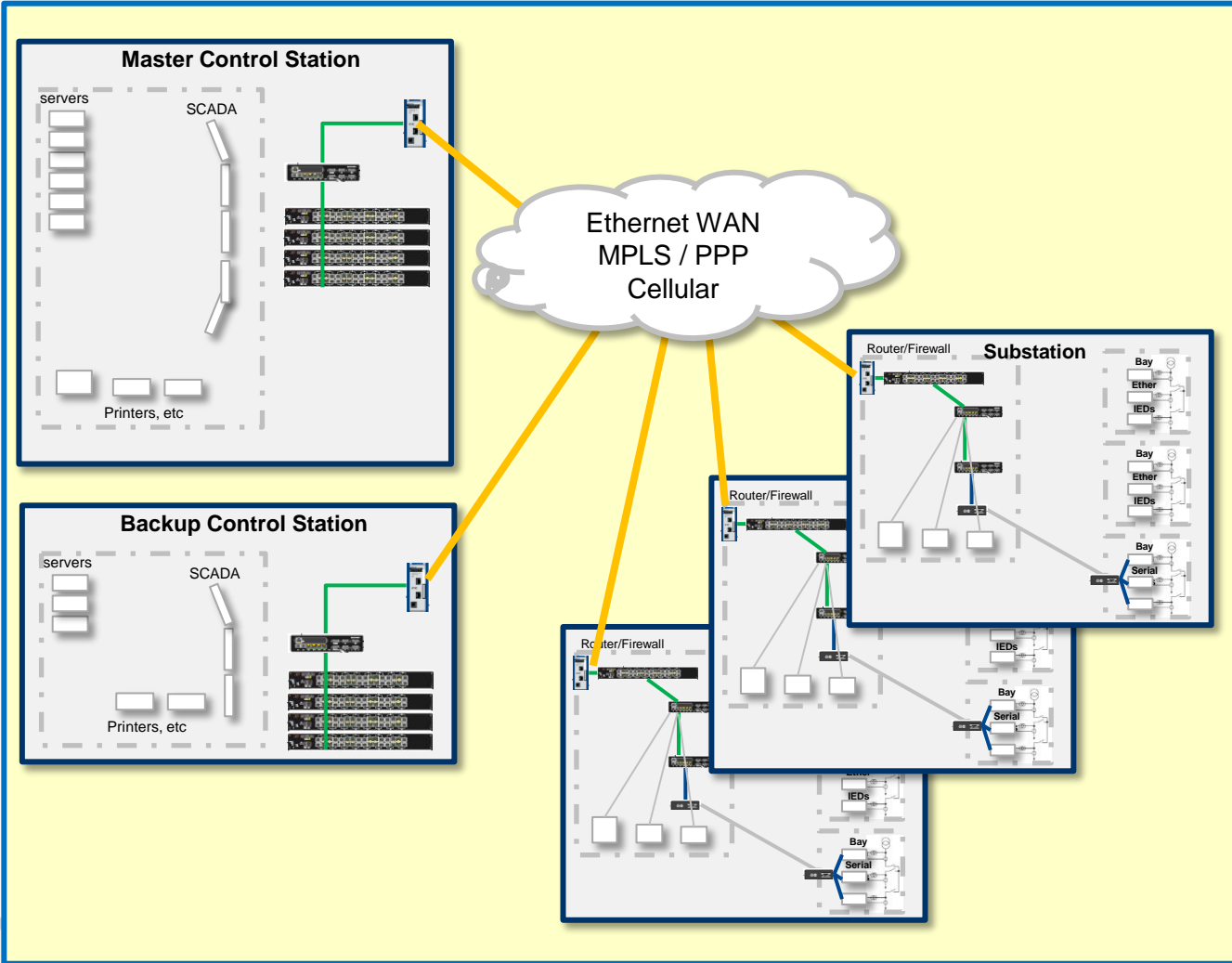
- Add remote communications between Master, backup and substations**
- Ethernet WAN
 - Cellular 3G
 - MPLS-PPP WAN

- Consider making these communications redundant**
- Robust communications keeps small issues small

- Redundancy Communication Options Include:**
- 2 different routes to the master
 - A master & backup station



... all are key to form a reliable, expandable infrastructure



Math you can do to justify an investment in redundancy


- Unplanned downtime calculator
 - How long will service be **impacted**?
 - Will end-customer service be **lost**?
 - How much effort is needed to **recover** and **restart** your process?
- Calculate your downtime cost per minute, per hour, per day

Downtime Calculator

$$\begin{aligned} & \$ \text{_____} \text{ per } \text{_____} \text{ (unit of time - e.g., hour) - Production Value} \\ & \times \text{_____} \text{ average MTTR (same time units as above)} \\ & \times \text{_____} \text{ number of downtime events per year} \\ & = \$ \text{_____} \text{ per year - downtime expense} \end{aligned}$$

Record Your Redundancy Choices

Record Your Choices **8**

 Switch / Router List - Network Design										
Project	Deb-Bay Substations 20-31									
Project Engineer	Andrew T.									
Use	Location /Name	External			Ethernet					
		Secure External Comms	L3 / Router	L2	10G ports	1G ports	10/100 ports	PoE ports	PoE+ ports	1588 precision time
External comm	Router 20	WAN	x			1	3			x
Bay 1	Switch B1			x			6			x
Bay 2	Switch B2			x			6			x
Control House	Switch CH Equip 3			x			8			
Bay 3	Terminal Server B3									

Redundancy	
2x power	Redund. nets
x	WAN/Cell
x	
x	
x	
x	

A - Specify Copper / Fiber Requirements

Best Practice **9**

Issue	You Need	Specify
Transmission Distance	100 Meters Max	Cat 5e/6
	2000 Meters Max	Multimode Fiber
	Over 2000 Meters	Single-Mode Fiber
Data Rates	100 Mb/s	Cat 5e
	1 Gb/s	Cat 6
	10 Gb/s	Fiber
Electrical Noise	Low Noise	Bonded Pairs • Unshielded
	Moderate Noise	Bonded Pairs • Foil Shielded
	High Noise	Bonded Pairs • Foil + Braid Shielded
Flexible Installation Continuous Flex Apps	No	Solid Conductors
	Yes	Stranded Conductors
Pairs	Most Apps	4-Pair Cable
	Special Needs	2-Pair Cable



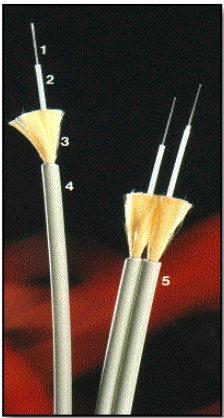
Industrial Copper, ALWAYS spec:

- Bonded Pair (see “9 tests” data)
- CAT5e or higher

B - Specify Jacket Requirements

Copper Cable

Issue	Specify
General Purpose for Most Applications	PVC
Sunlight/UV Resistance	Any
Oil Resistance	Most
Chemical and Fuel Resistance	FEP
Temperatures to 150°C	FEP
Plenum Rating	FEP
Low Generation, No Toxins When Burned	LSZH
High Mechanical Stress (Abrasion, Cut Through)	Polyurethane
Halogen Free	LSZH
Continuous Flex	TPE
Weldsplatter Resistance	TPE
Direct Burial	Polyethylene
Maximum Mechanical Protection	Armoring



Fiber-Optic Cable

Issue	Look for
General Purpose for Most Applications	PVC
Addition Chemical and Abrasion Resistance	CPE

C - Specify Standards, Connector Type, and Buy vs. Build

Best Practice **9**

Issue	Specify
Tray Application	UL PLTC (300V) UL TC-ER (600V)
600V	600 AWM Style
Mining	MSHA
Regulatory	NEC/CEC and Local Codes



Issue	You Need	Specify
IP20 (Most Apps)	Standard Duty	RJ 45
	Heavy Duty	Full-Metal-Body RJ45
IP67 or Washdown	4-Pair Cable	Ruggedized ODVA RJ45
	2-Pair Cable	M12
Cable Shielding	Yes	Shielded Connector
	No	Unshielded Connector

Issue	Make	Buy
Cost	Lower	Higher
Skill	Higher	Lower
Fine-Tune Custom Lengths	Yes	No
Installation Speed	Slower	Faster
Testing	On-site testing	Factory tested



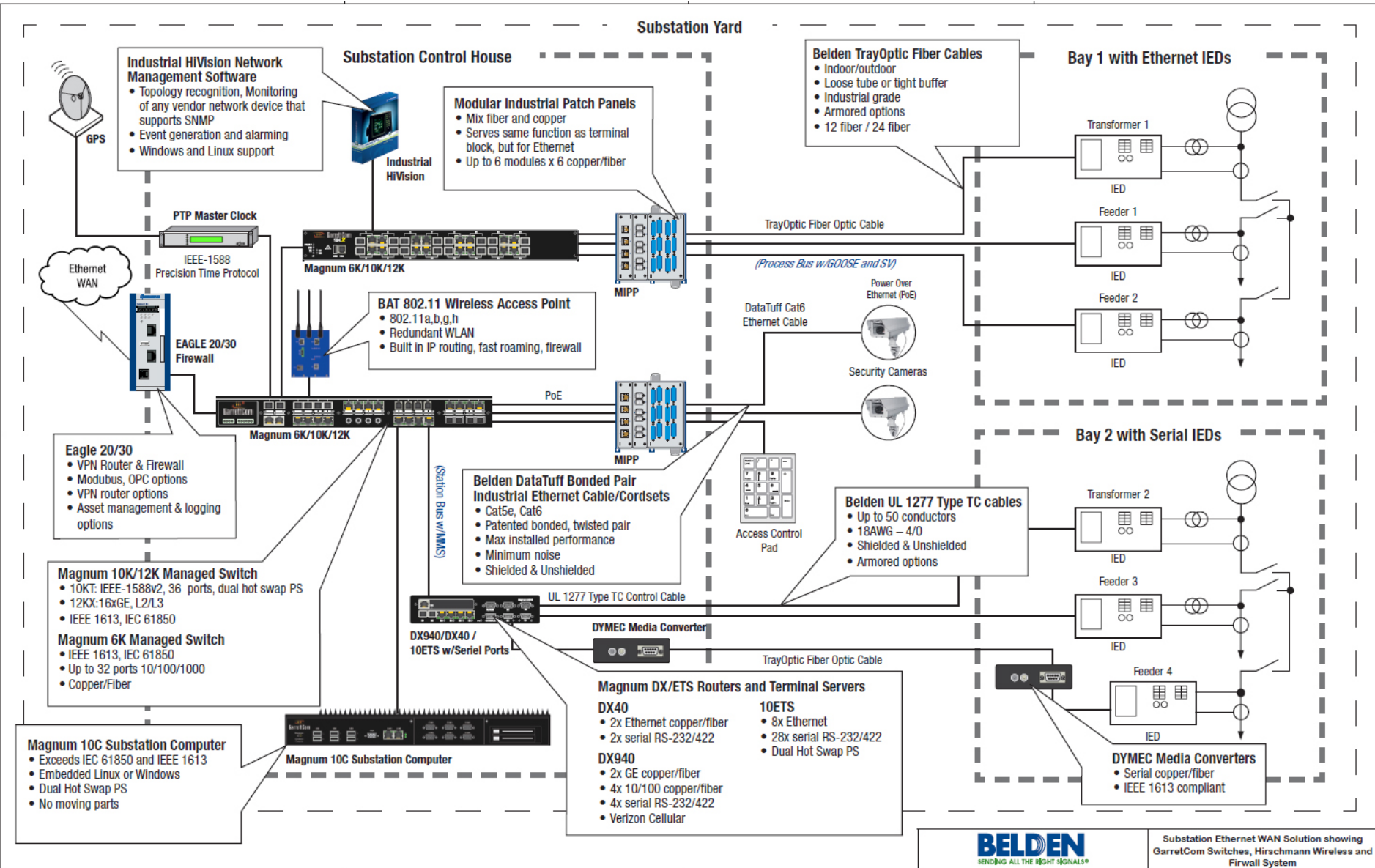
Keys to Project and Operations Success

Best Practice **10**

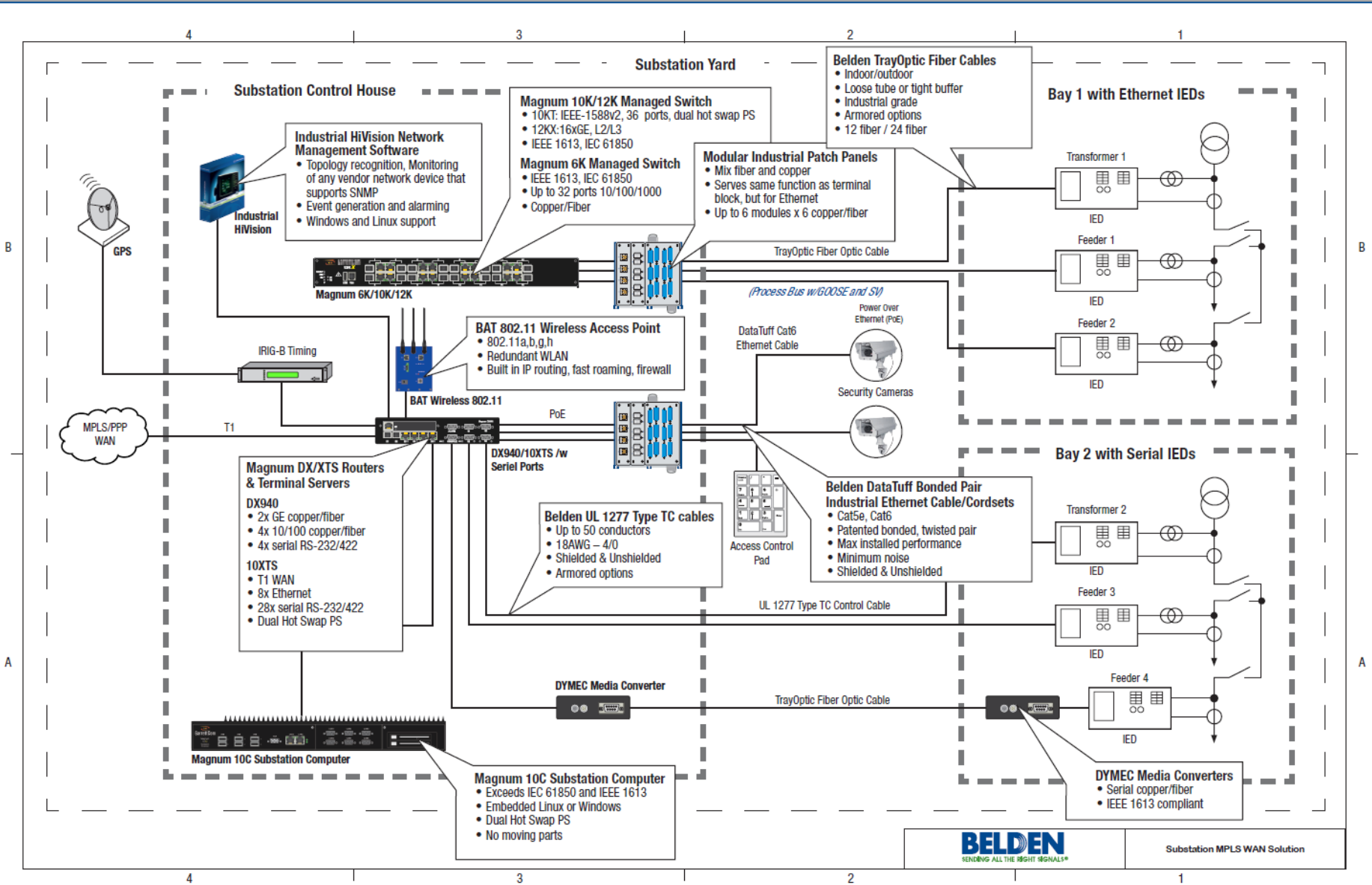
Industrial Networking Project Checklist

Need		How Belden Can Help
Manage	<input type="checkbox"/> Manage my entire project	Provide a dedicated resource to work as customer staff
Design	<input type="checkbox"/> Review my design & highlight areas of risk	Email, Fax & phone consultation
	<input type="checkbox"/> Assist with my design in a few key areas	Email, Fax & phone consultation
	<input type="checkbox"/> Assess my situation & create my design	Onsite meeting & comprehensive network design
Install	<input type="checkbox"/> Preconfigure switches / routers	
	<input type="checkbox"/> Provide industrial installation guidelines	
	<input type="checkbox"/> Create custom installation instructions & drawings	Recommend experienced Belden System Integrator or partner
	<input type="checkbox"/> Perform the installation	Recommend experienced Belden System Integrator or partner
	<input type="checkbox"/> Perform security vulnerability testing	Onsite testing and assesment
	<input type="checkbox"/> Perform network validation	Onsite testing and assesment
Startup	<input type="checkbox"/> Perform startup	Recommend experienced Belden System Integrator or partner
	<input type="checkbox"/> Provide troubleshooting	Onsite troubleshooting
Operate	<input type="checkbox"/> Dedicated onsite engineering service	
Maintain	<input type="checkbox"/> Stock spares	We review your application & needs & provide recommendations
	<input type="checkbox"/> Stock preconfigured spares	
	<input type="checkbox"/> Firmware	Keep your hardware current
	<input type="checkbox"/> Switch warranty	Extended Warranty
	<input type="checkbox"/> Industrial HiVision Service Contract	Keep your software current
	<input type="checkbox"/> Advanced replacement for faulty devices	
	<input type="checkbox"/> Remote troubleshooting	
	<input type="checkbox"/> Dedicated technical support contact	Get help from someone that knows you and your application
	<input type="checkbox"/> On-site troubleshooting	
	<input type="checkbox"/> Troubleshooting procedures	
	<input type="checkbox"/> Troubleshooting tools	
<input type="checkbox"/> Training for maintenance team		
Upgrade	<input type="checkbox"/> Assess planned network changes & highlight areas of risk	Fax & phone consultation
	<input type="checkbox"/> Onsite visit if needed	

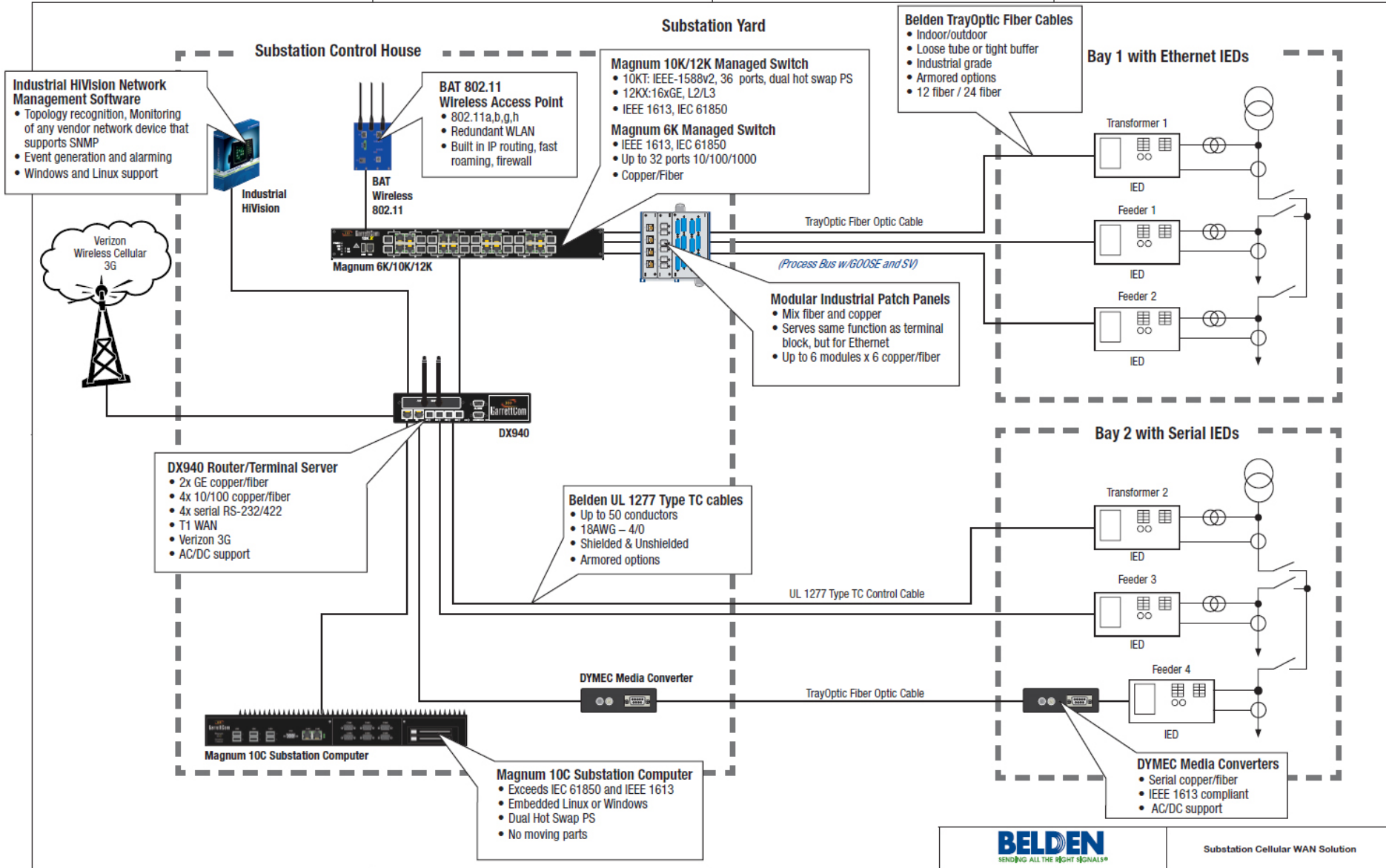
Popular Config Diagram 1 – Ethernet WAN



Popular Config Diagram 2 – MPLS WAN



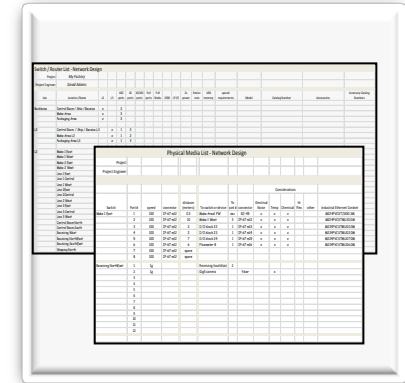
Popular Config Diagram 3 – Cellular WAN



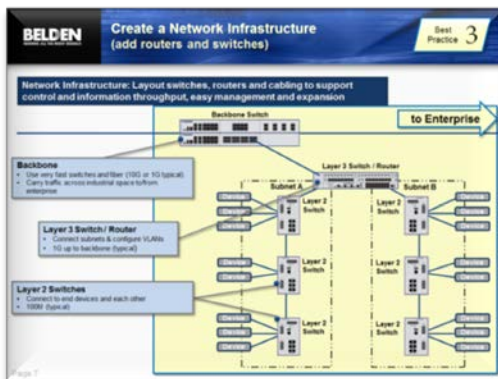
Summary

Belden's Substation Communications Infrastructure design overview enables you to compare your designs to industry best-practices.

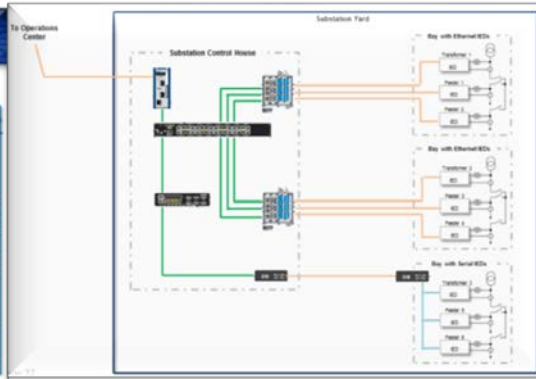
- 10 easy steps
- Provides you with insight & ideas for improvement
- Helps us better understand your needs
- The things we'll use are:



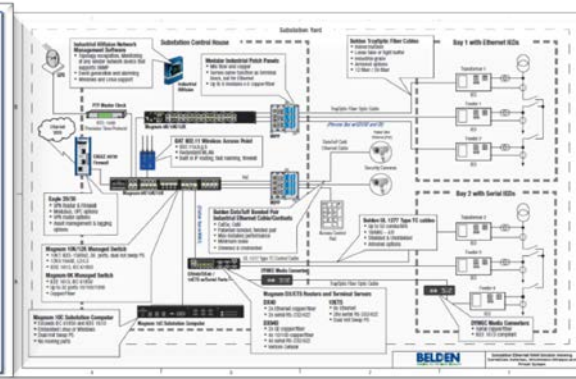
Excel Worksheets



Best Practices



Examples



Popular Configuration Drawings



Product Guides

Additional Resources & Assistance

1. Listen to the recorded webinar of this presentation:
 - [Substation Communications Design Legacy to IEC 61850 Recorded Webinar](#)
2. Obtain further Substation Communication resources from our website:
 - www.belden.com/power-td/
 - This webpage includes substation communication diagrams and other useful tools
3. Contact a Belden representative for assistance:
 - Call 510-438-9071 if you are in the U.S. or Canada
 - Or complete the form at www.belden.com/contact/

Thank you for your interest in this presentation!



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