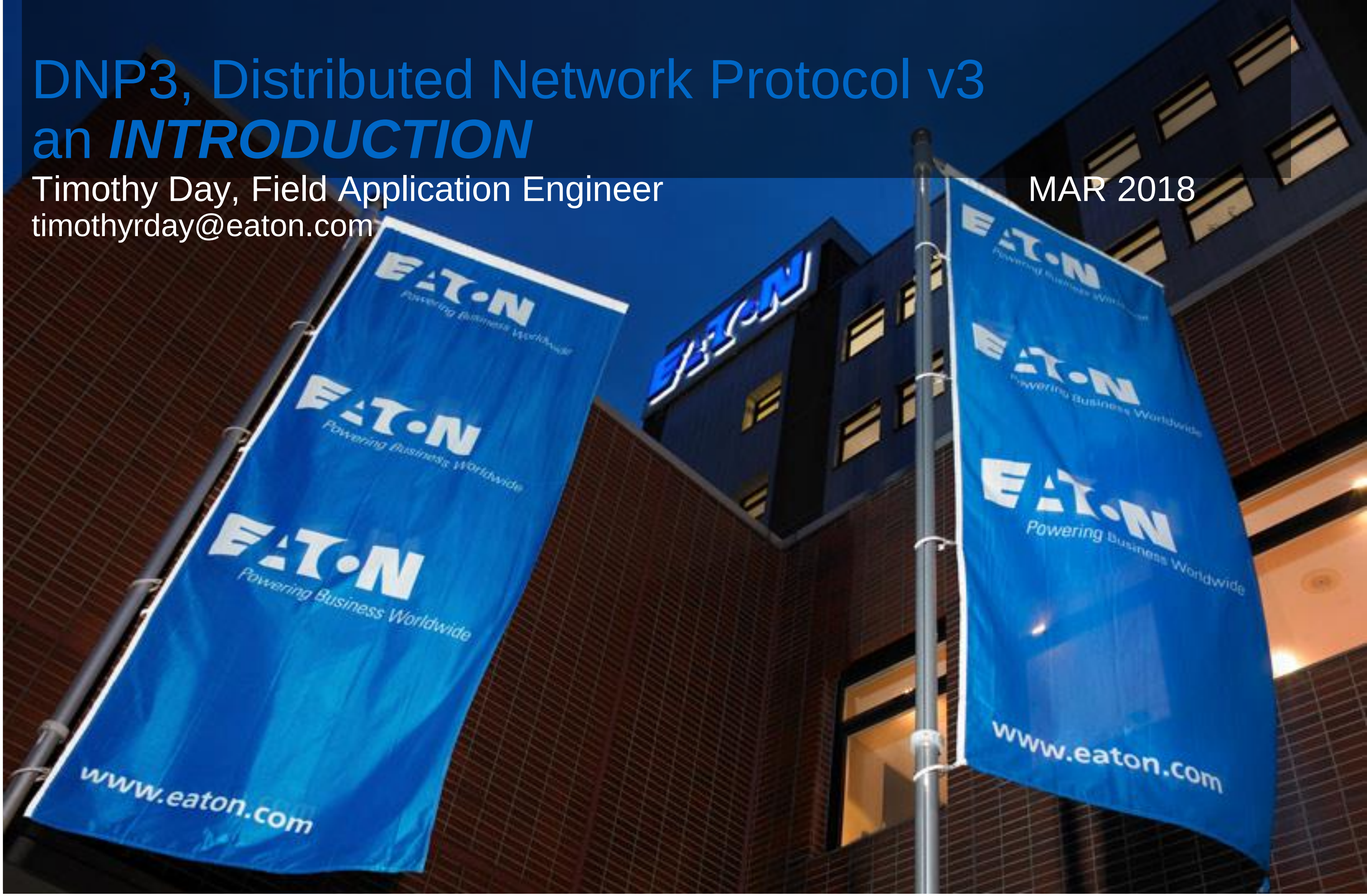
# DNP3, Distributed Network Protocol v3
# an ***INTRODUCTION***

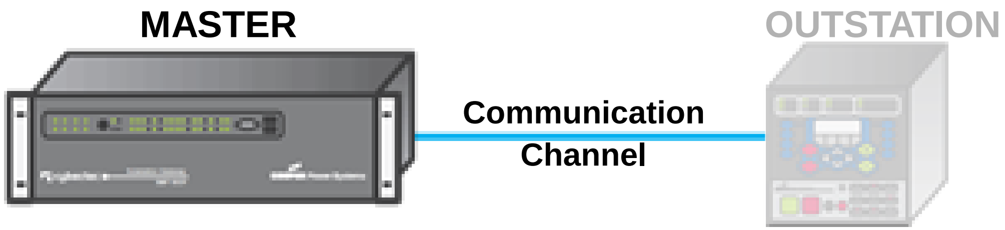
Timothy Day, Field Application Engineer
timothyrday@eaton.com

MAR 2018



Powering Business Worldwide

# Master



MASTER

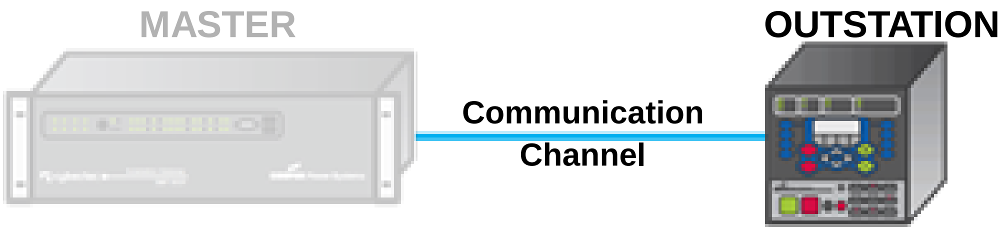
Communication Channel

OUTSTATION

- a.k.a: Master Terminal Unit (MTU), SCADA, HMI, Client or Control Center
- Performs data retrieval and archiving
- Performs control operations and configuration changes to the Outstation
- Front-End Processor
- Typically the communications interface

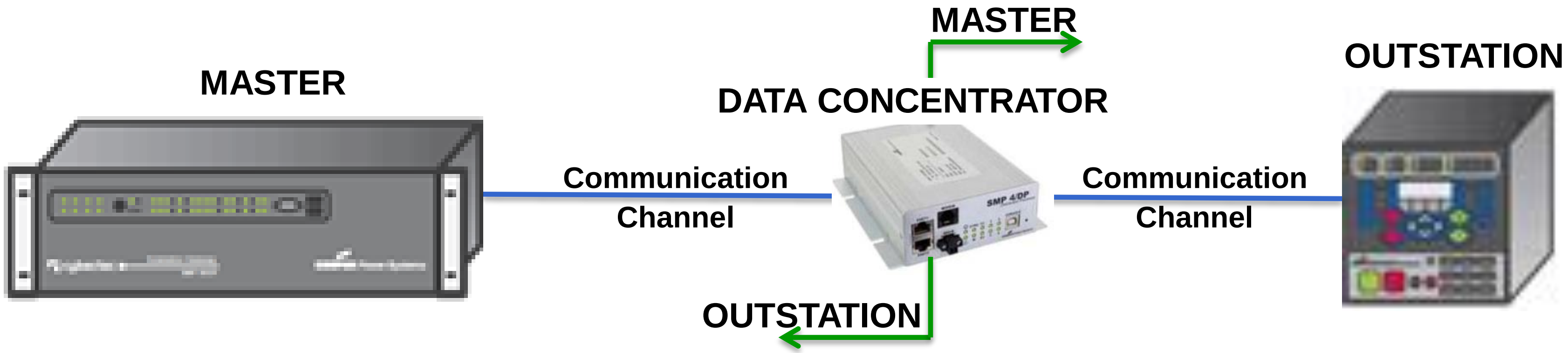
Powering Business Worldwide

# Outs



- The Outstation holds the information
- Also called:
  - Slave or Remote Device
  - SCADA Server
  - Controlled Station
  - IED: Intelligent Electronic Device
  - PLC: Programmable Logic Controller
  - RTU: Remote or Network Terminal Unit
  - Gateway or Data Concentrator

# Data Concentrator



- DATA CONCENTRATOR
  - Acts as MASTER to OUTSTATION(S)
  - Acts as OUTSTATION to the MASTER

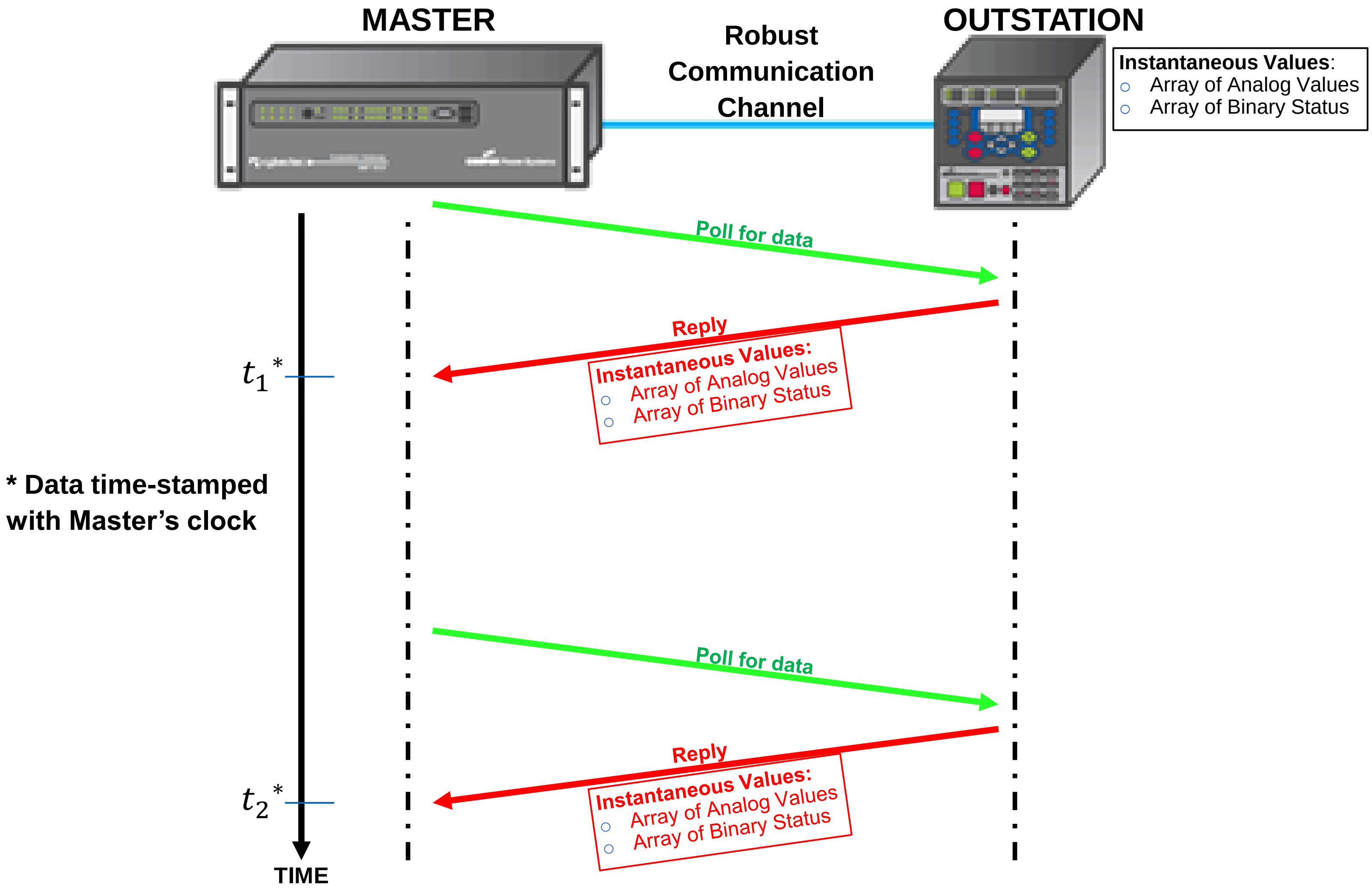
# DNP3 History

- Prior to 1993: Westronics a.k.a. GE Harris, an RTU vendor, implemented 100s of proprietary utility protocols.
- An open protocol, standardized and accommodating the needs of the utility sector, was needed.
- New protocol proposed
  - GE Harris would develop then release to the industry
  - Incorporate the best features of existing protocols
  - Include new features
  - Independent users' group  would control the specification
  - Utilities and vendors would be members.
- 1993: DNP V3.00 released to the public domain. (dnp.org)
- DNP V1.00 and DNP V2.00 are earlier, proprietary Westronics protocols.

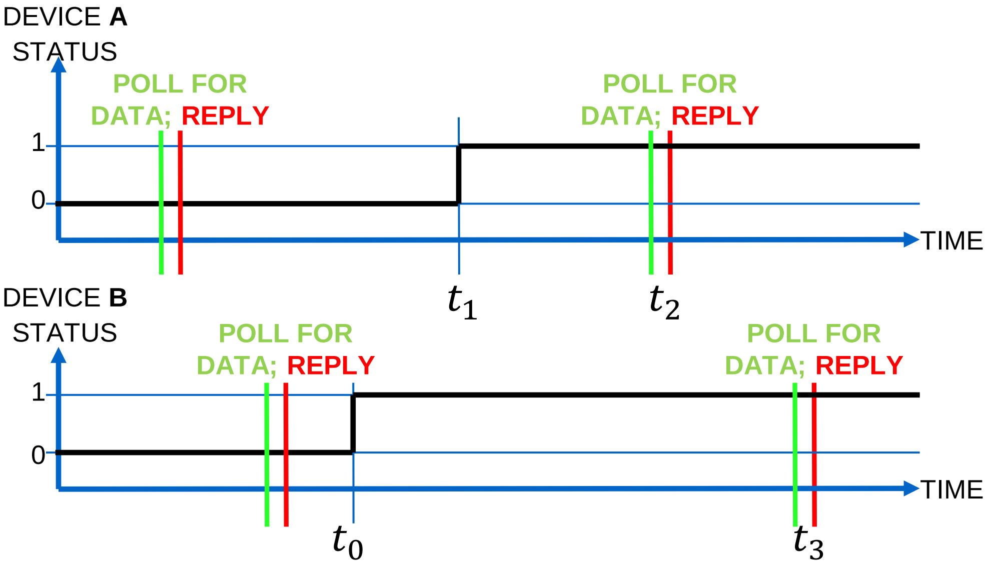
# Protocol Comparison
# Modbus vs. DNP3

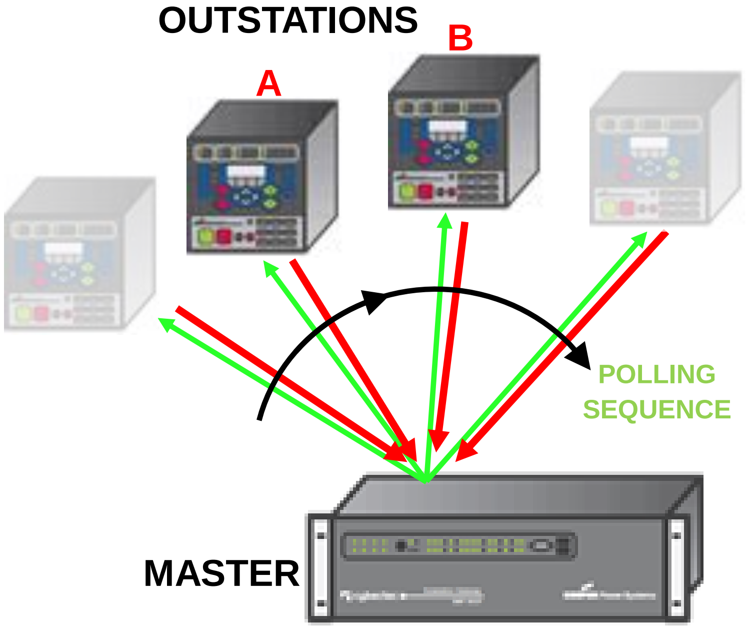
- Modbus Background. Developed by Modicon in 1979
  - Preceded DNP
  - Widely used in industrial plants
  - Initially designed for ***local*** serial communications.
- Modbus Applications
  - Dedicated wire or fiber connection between stations
  - Short distances
  - Controlled environment and communication dynamics
  - Robust, dedicated physical connection expected
  - Tolerable Sequence of Events timing incoherency as acquired by Master.

# Protocol Comparison Modbus

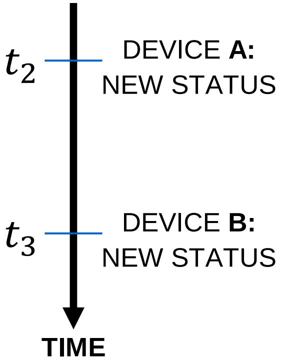


# Protocol Comparison
# Modbus: Possible Timing Incoherency





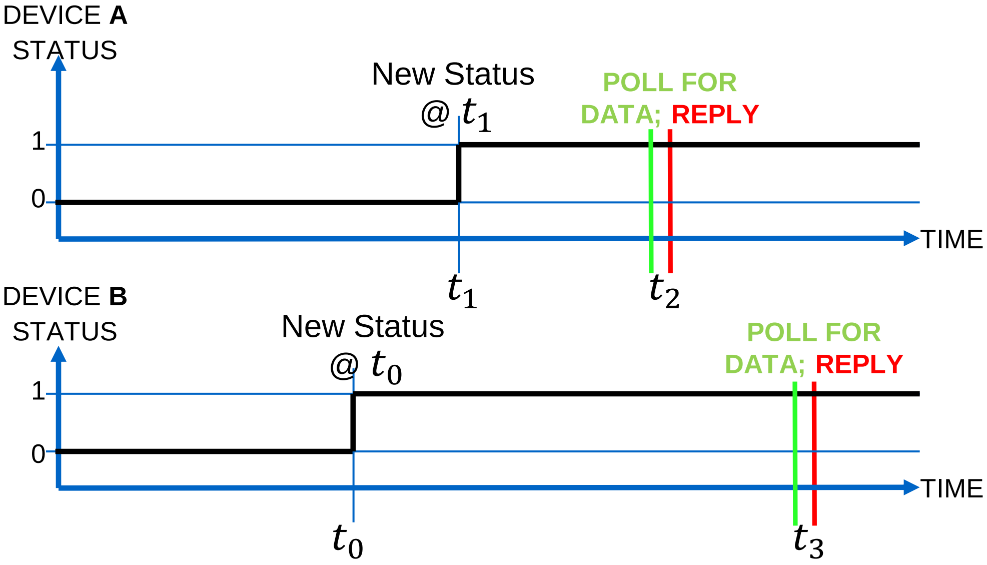
**The Master's clock time-stamps the devices' status changes incoherently.**

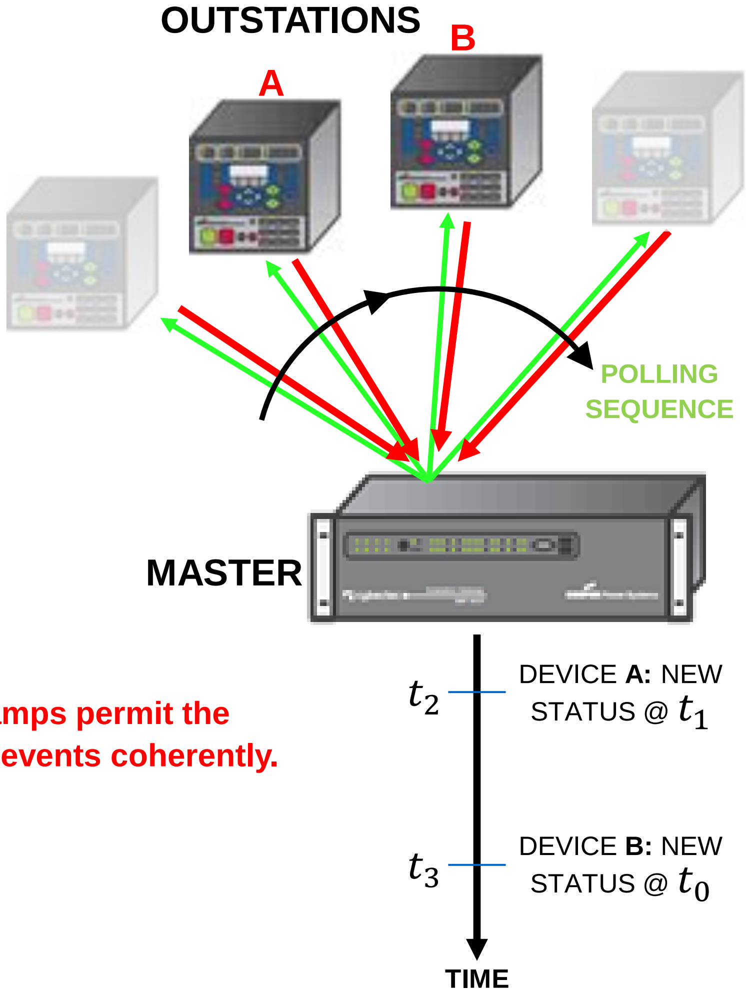


# Protocol Comparison
# Modbus vs. DNP3

- Why DNP3? What advantages over Modbus?
- DNP3 Basic Design Objectives:
  - ***Remote*** communications
  - Limited bandwidth
  - Possible use with Modems: more time for handshaking
  - Interrupted communications
    - Radio interference; Terrain, Trees, Buildings; Remote power outages
    - Outstation stores event data until retrieved / acknowledged by Master
  - Event Time-stamping
    - Outstation time-stamps, not the Master
    - Permits coherent sequencing of events at the Master

# Protocol Comparison
# **DNP3**: Correct Event Timing

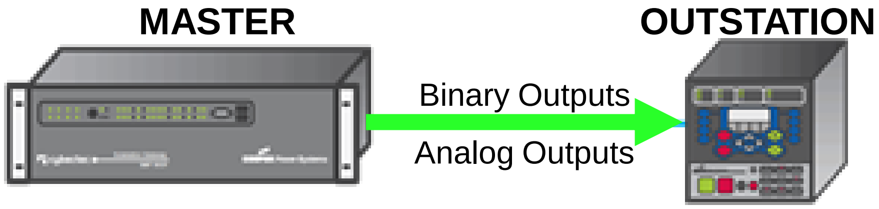




**Outstation time-stamps permit the Master to organize events coherently.**

Powering Business Worldwide

# DNP3
# Data Flow



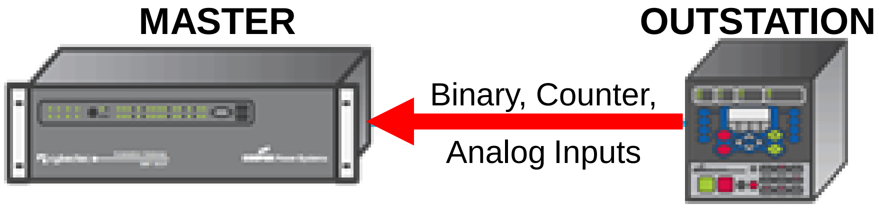
MASTER

OUTSTATION

Binary Outputs

Analog Outputs

- Outputs
  - Sent from Master to Outstation
  - Binary: Control, Enable, Disable
  - Analog: Update programming setpoints



MASTER

OUTSTATION

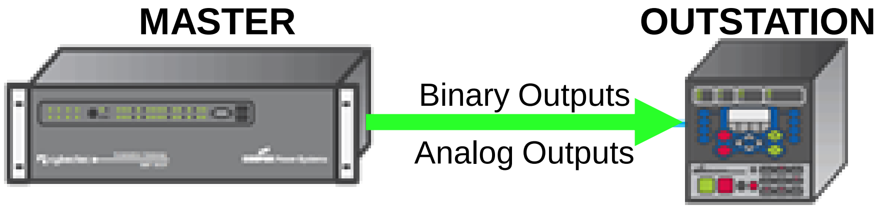
Binary, Counter,

Analog Inputs

- Inputs
  - Sent from Outstation to Master
  - Binary: Status
  - Counter: e.g., Number of Operations
  - Analog: e.g., Volt, Amp, Watt, var metering values

# DNP3
# Data Organized into Object Groups

Various Examples of Object Groups

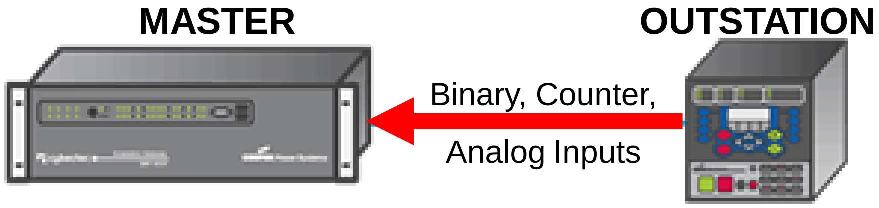

MASTER

OUTSTATION

Binary Outputs

Analog Outputs

- Outputs
  - Binary: Control, Enable, Disable
  - Analog: Alter programming setpoints


MASTER

OUTSTATION

Binary, Counter,

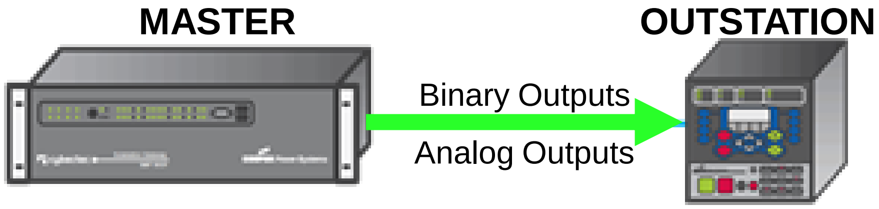
Analog Inputs

- Inputs
  - Binary: Read Status
  - Counter: e.g., Read Number of Operations
  - Analog: e.g., Read Volt, Amp, Watt, var metering values

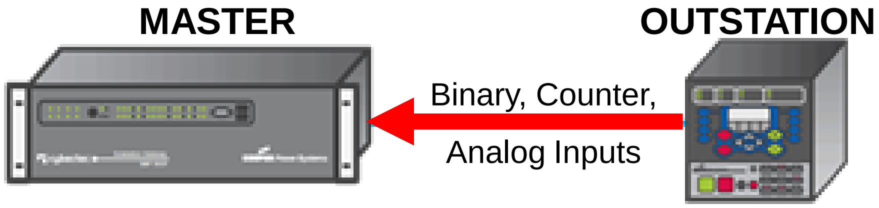
# DNP3
# Object Group Designations by Number

Various Examples of Object Groups

- Outputs
  - Binary: **Object Groups 10, 12**
  - Analog: **Object Groups 40, 41**



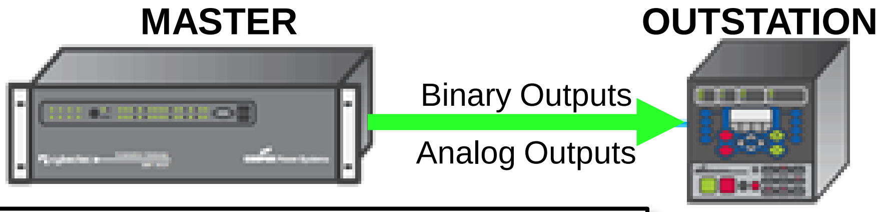
- Inputs
  - Binary: **Object Groups 1, 2**
  - Counter: **Object Groups 20, 21, 22, 23**
  - Analog: **Object Groups 30, 32**



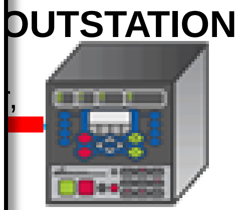
# Purpose of **Object Groups**: DNP3

Various Examples of Object Groups

- Outputs

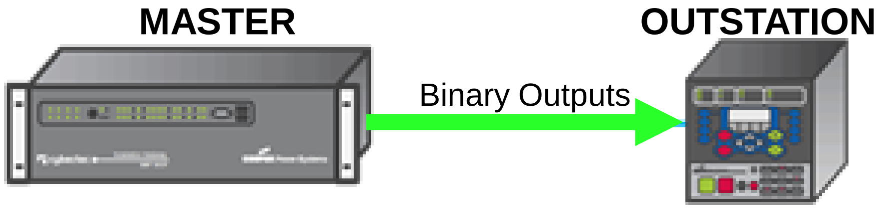


**Permit coherent, numerically-identified, negotiated exchange between Master and Outstation of data performing a particular function.**



- Counter: **Object Groups 20, 21, 22, 23**
- Analog: **Object Groups 30, 32**

# DNP3
# Object Group Designations by Number

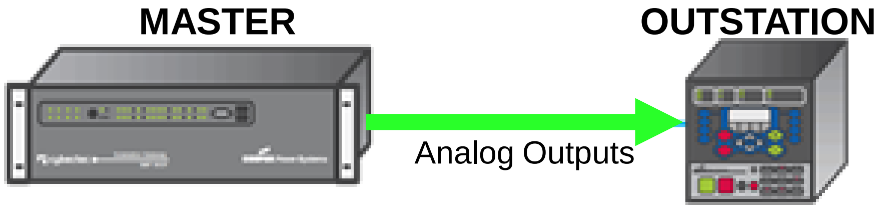


- Binary Outputs
  - **Object Group 10**

    **for reading the binary value in the Outstation's register**
  - **Object Group 12**

    **for writing a new binary value to the Outstation's register**

# DNP3
# Object Group Designations by Number

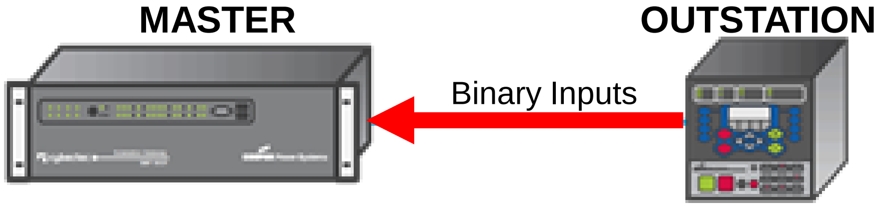


- Analog Outputs
  - **Object Group 40**

    **for reading the analog value in the Outstation’s register**
  - **Object Group 41**

    **for writing a new analog value to the Outstation’s register**

# DNP3
# Object Group Designations by Number

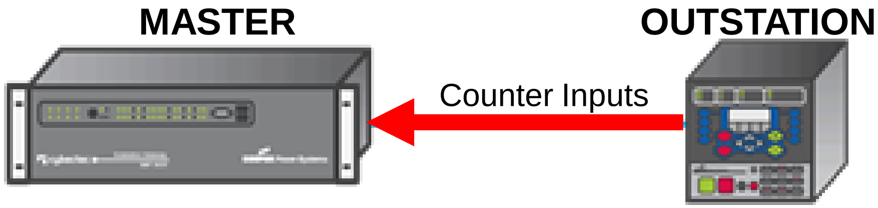


- Binary Inputs
  - **Object Group 1**

    **for reading a *static* binary value in the Outstation**
  - **Object Group 2**

    **for reading a *changed* binary value in the Outstation**

# DNP3
# Object Group Designations by Number



- Counter Inputs
  - **Object Group 20**

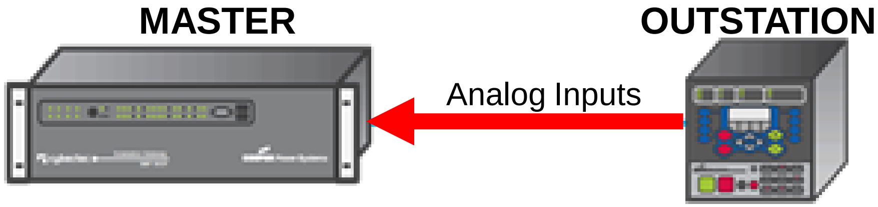
    **for reading a *static* counter value from the Outstation**
  - **Object Group 21**

    **for reading a *static* frozen counter value from the Outstation**
  - **Object Group 22**

    **for reading a *changed* counter value from the Outstation**
  - **Object Group 23**

    **for reading a *changed* frozen counter value from the Outstation**

# DNP3
# Object Group Designations by Number

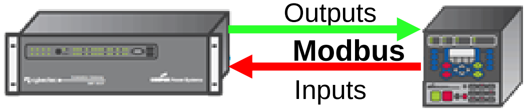


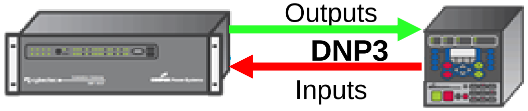
- Analog Inputs
  - **Object Group 30**

    **for reading a *static* analog value in the Outstation**
  - **Object Group 32**

    **for reading a *changed* analog value in the Outstation**

# Introducing Data Types
# Modbus vs. DNP3



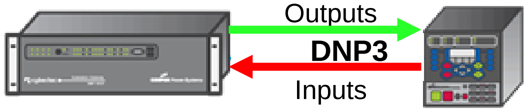


| Function | Modbus | | DNP3 | |
|---|---|---|---|---|
| | Name | Data Type | Name | Data Type(s) |
| **Binary Output** | Coil | bit | Control Relay Output Block (CROB) | bit |
| **Analog Output** | Holding Register | 16-bit integer | Analog Output | 16-bit integer<br>32-bit integer<br>32-bit float<br>* 64-bit float |
| **Binary Input** | Discrete Input | bit | Binary Input | bit |
| **Analog Input** | Input Register | 16-bit integer | Analog Input | 16-bit integer<br>32-bit integer<br>32-bit float<br>* 64-bit float |
| **Counter Input** | Use Input Register for Analogs and Counters | | Counter Input | 16-bit integer<br>32-bit integer |

* Infrequently used / supported

EATON
Powering Business Worldwide

# Reviewing Object Groups: DNP3

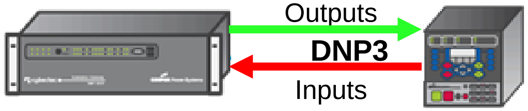


| Function |
|---|
| **Binary Output** |
| **Analog Output** |
| **Binary Input** |
| **Analog Input** |
| **Counter Input** |

| DNP3 | |
|---|---|
| Name | Data Type(s) |
| Control Relay Output Block (CROB) | bit |
| Analog Output | 16-bit integer<br>32-bit integer<br>32-bit float<br>64-bit float |
| Binary Input | bit |
| Analog Input | 16-bit integer<br>32-bit integer<br>32-bit float<br>64-bit float |
| Counter Input | 16-bit integer<br>32-bit integer |

Powering Business Worldwide

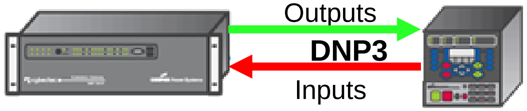
# Reviewing Object Groups: DNP3



| Function | DNP3 | |
|---|---|---|
| | Name | Data Type(s) |
| **Binary Output** | Control Relay Output Block (CROB) | bit |
| **Analog Output** | Analog Output | 16-bit integer<br>32-bit integer<br>32-bit float<br>* 64-bit float |
| **Binary Input** | Binary Input | bit |
| **Analog Input** | Analog Input | 16-bit integer<br>32-bit integer<br>32-bit float<br>* 64-bit float |
| **Counter Input** | Counter Input | 16-bit integer<br>32-bit integer |

* Infrequently used / supported

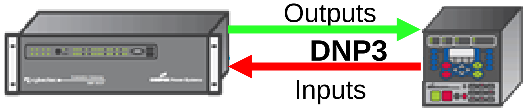
# Reviewing Object Groups: DNP3



| Function | DNP3 | | |
|---|---|---|---|
| | Name | | Data Type(s) |
| Binary Output | Control Relay Output Block (CROB) | | bit |
| Analog Output | Analog Output | | 16-bit integer<br>32-bit integer<br>32-bit float<br>* 64-bit float |
| Binary Input | Binary Input | | bit |
| Analog Input | Analog Input | | 16-bit integer<br>32-bit integer<br>32-bit float<br>* 64-bit float |
| Counter Input | Counter Input | | 16-bit integer<br>32-bit integer |

* Infrequently used / supported

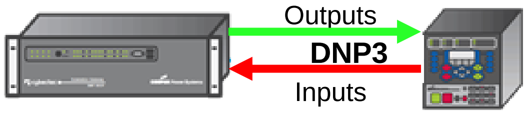
# Reviewing Object Groups: DNP3



| Function | DNP3 | | |
|---|---|---|---|
| | Name | Object Groups | Data Type(s) |
| **Binary Output** | Control Relay Output Block (CROB) | 10<br>12 | bit |
| **Analog Output** | Analog Output | 40<br>41 | 16-bit integer<br>32-bit integer<br>32-bit float<br>* 64-bit float |
| **Binary Input** | Binary Input | 1<br>2 | bit |
| **Analog Input** | Analog Input | 30<br>32 | 16-bit integer<br>32-bit integer<br>32-bit float<br>* 64-bit float |
| **Counter Input** | Counter Input | 20<br>22 | 16-bit integer<br>32-bit integer |

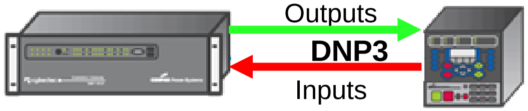
* Infrequently used / supported

# Reviewing Object Groups: DNP3



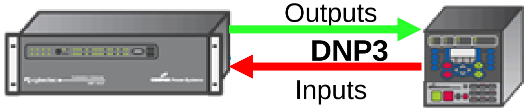
| Function | DNP3 | | |
|---|---|---|---|
| | Name | Object Groups | Object Group Purpose |
| **Binary Output** | Control Relay Output Block (CROB) | 10<br>12 | Read the state<br>Operate (write a new state) |
| **Analog Output** | Analog Output | 40<br>41 | Read the setting<br>Write a new setting |
| **Binary Input** | Binary Input | 1<br>2 | Read the static bit<br>Read any bit **changes** |
| **Analog Input** | Analog Input | 30<br>32 | Read the static analog Read<br>any analog **changes** |
| **Counter Input** | Counter Input | 20<br>22 | Read the static count<br>Read any count **changes** |

# Introducing Data Format Variations: DNP3



| Function | DNP3 | | | |
|---|---|---|---|---|
| | Name | Object Groups | Data Type(s) | Variations |
| Binary Output | Control Relay Output Block (CROB) | 10<br>12 | bit | 1, 2<br>1, 2, 3 |
| Analog Output | Analog Output | 40<br>41 | 16-bit integer<br>32-bit integer<br>32-bit float<br>64-bit float | 1, 2, 3, 4<br>1, 2, 3, 4 |
| Binary Input | Binary Input | 1<br>2 | bit | 1, 2<br>1, 2, 3 |
| Analog Input | Analog Input | 30<br>32 | 16-bit integer<br>32-bit integer<br>32-bit float<br>64-bit float | 1,2,3,4,5,6<br>1,2,3,4,5,6,7,8 |
| Counter Input | Counter Input | 20<br>22 | 16-bit integer<br>32-bit integer | 1, 2, 5, 6<br>1, 2, 5, 6 |

# Purpose of **Variations**: DNP3

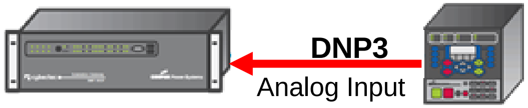


| Function | DNP3 | | | |
|---|---|---|---|---|
| | Name | Object Groups | Data Type(s) | Variations |
| Binary Output | Control Relay Output Block (CROB) | 10<br>12 | bit | 1, 2<br>1, 2, 3 |
| Input | | 2 | | 1, 2, 3 |
| Analog Input | Analog Input | 30<br>32 | 16-bit integer<br>32-bit integer<br>32-bit float<br>64-bit float | 1,2,3,4,5,6<br>1,2,3,4,5,6,7,8 |
| Counter Input | Counter Input | 20<br>22 | 16-bit integer<br>32-bit integer | 1, 2, 5, 6<br>1, 2, 5, 6 |

**Permit negotiated exchange of data formatted in a particular fashion as indicated by a Variation Number.**

# Data Format Variation Example

- Analog Inputs



  - **Object Group 30**

    **for reading a *static* analog value**

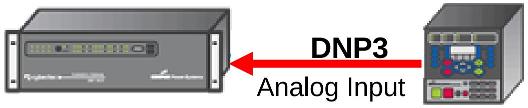
    - **VAR 1: 32-bit Integer with Flag**
    - **VAR 2: 16-bit Integer with Flag**
    - **VAR 3: 32-bit Integer**
    - **VAR 4: 16-bit Integer**
    - **VAR 5: 32-bit Float with Flag**
    - *** VAR 6: 64-bit Float with Flag**

| Function | DNP3 | | | |
|---|---|---|---|---|
| | Name | Object Groups | Data Type(s) | Variations |
| **Analog Input** | Analog Input | [✓ 30]<br>32 | 16-bit integer<br>32-bit integer<br>32-bit float<br>64-bit float | [✓ 1,2,3,4,5,6]<br>1,2,3,4,5,6,7,8 |

* Infrequently used / supported

# Data with FLAG

- Analog Inputs



  - **Object Group 30**

    **for reading a *static* analog value in the Outstation**

    - **VAR 1: 32-bit Integer with Flag**
    - **VAR 2: 16-bit Integer with Flag**
    - **VAR 3: 32-bit Integer**

➢ The flag helps determine data quality. Examples:

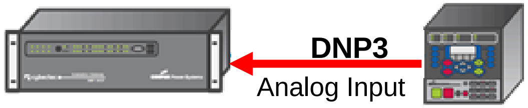
- ➢ Data source on-line
- ➢ Data source restarted
- ➢ Communications lost with a downstream source
- ➢ Data are forced
- ➢ Value is over range.

***Reference:***

**DNP3 Technical Bulletin 2003-002**
**Object Flags**

# Data Format; More Variations

- Analog Inputs



  - **Object Group 32**

    **for reading a *changed* analog value in the Outstation**

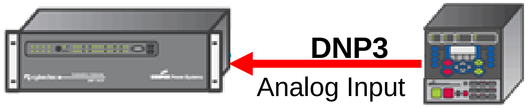
    - **VAR 1: 32-bit Integer with Flag**
    - **VAR 2: 16-bit Integer with Flag**
    - **VAR 3: 32-bit Integer with Flag and Time**
    - **VAR 4: 16-bit Integer with Flag and Time**
    - **VAR 5: 32-bit Float with Flag**
    - *** VAR 6: 64-bit Float with Flag**
    - **VAR 7: 32-bit Float with Flag and Time**
    - *** VAR 8: 64-bit Float with Flag and Time**

| Function | DNP3 | | | |
|---|---|---|---|---|
| | Name | Object Groups | Data Type(s) | Variations |
| **Analog Input** | Analog Input | 30 (static)<br>32 (changed) | 16-bit integer<br>32-bit integer<br>32-bit float<br>64-bit float | 1,2,3,4,5,6<br>1,2,3,4,5,6,7,8 |

* Infrequently used / supported

# Data Format; More Variations

- Analog Inputs



  - **Object Group 32**

    **for reading a *changed* analog value in the Outstation**

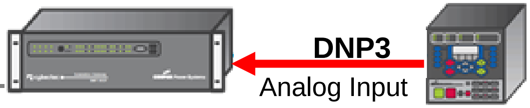
    - **VAR 1: 32-bit Integer with Flag**
    - **VAR 2: 16-bit Integer with Flag**
    - **VAR 3: 32-bit Integer with Flag and Time**
    - **VAR 4: 16-bit Integer with Flag and Time**
    - **VAR 5: 32-bit Float with Flag**
    - *** VAR 6: 64-bit Float with Flag**
    - **VAR 7: 32-bit Float with Flag and Time**
    - *** VAR 8: 64-bit Float with Flag and Time**

**Outstation returns time-of-occurrence; when the value changed.**

| Function | DNP3 | | | |
|---|---|---|---|---|
| | Name | Object Groups | Data Type(s) | Variations |
| **Analog Input** | Analog Input | 30 (static)<br>32 (changed) | 16-bit integer<br>32-bit integer<br>32-bit float<br>64-bit float | 1,2,3,4,5,6<br>1,2,3,4,5,6,7,8 |

* Infrequently used / supported

# Data Format; Some Variation Comparisons



- Analog Inputs

- **Object Group 30**

  **for reading a *static* analog value**

  - **VAR 1: 32-bit Integer with Flag**
  - **VAR 2: 16-bit Integer with Flag**
  - **VAR 3: 32-bit Integer**
  - **VAR 4: 16-bit Integer**
  - **VAR 5: 32-bit Float with Flag**
  - **VAR 6: 64-bit Float with Flag**

- **Object Group 32**

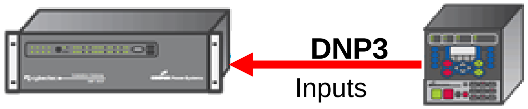
  **for reading a *changed* analog value**

  - **VAR 1: 32-bit Integer with Flag**
  - **VAR 2: 16-bit Integer with Flag**
  - **VAR 3: 32-bit Integer with Flag and Time**
  - **VAR 4: 16-bit Integer with Flag and Time**
  - **VAR 5: 32-bit Float with Flag**
  - **VAR 6: 64-bit Float with Flag**
  - **VAR 7: 32-bit Float with Flag and Time**
  - **VAR 8: 64-bit Float with Flag and Time**

| Function | DNP3 | | | |
|---|---|---|---|---|
| | Name | Object Groups | Data Type(s) | Variations |
| **Analog Input** | Analog Input | 30 (static)<br>32 (changed) | 16-bit integer<br>32-bit integer<br>32-bit float<br>64-bit float | 1,2,3,4,5,6<br>1,2,3,4,5,6,7,8 |

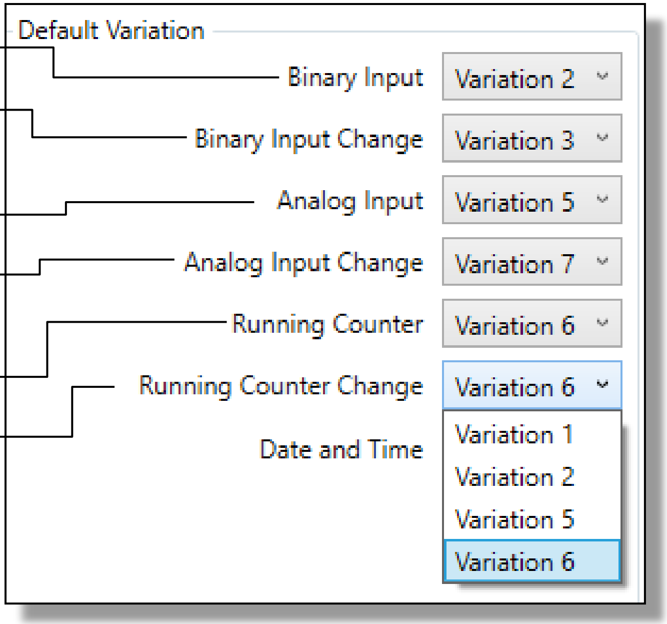
EATON
Powering Business Worldwide

# Default Variations: Programming the Outstation



| DNP3 | | | |
|---|---|---|---|
| Name | Object Groups | Data Type(s) | Variations |
| Binary Input | 1 (static)<br>2 (changed) | bit | 1, 2<br>1, 2, 3 |
| Analog Input | 30 (static)<br>32 (changed) | 16-bit integer<br>32-bit integer<br>32-bit float<br>64-bit float | 1,2,3,4,5,6<br>1,2,3,4,5,6,7,8 |
| Counter Input | 20 (static)<br>22 (changed) | 16-bit integer<br>32-bit integer | 1, 2, 5, 6<br>1, 2, 5, 6 |

**Example: portion of Outstation's configuration dialog.**

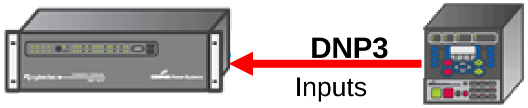


Default Variation

| | |
|---|---|
| Binary Input | Variation 2 |
| Binary Input Change | Variation 3 |
| Analog Input | Variation 5 |
| Analog Input Change | Variation 7 |
| Running Counter | Variation 6 |
| Running Counter Change | Variation 6 |
| Date and Time | |

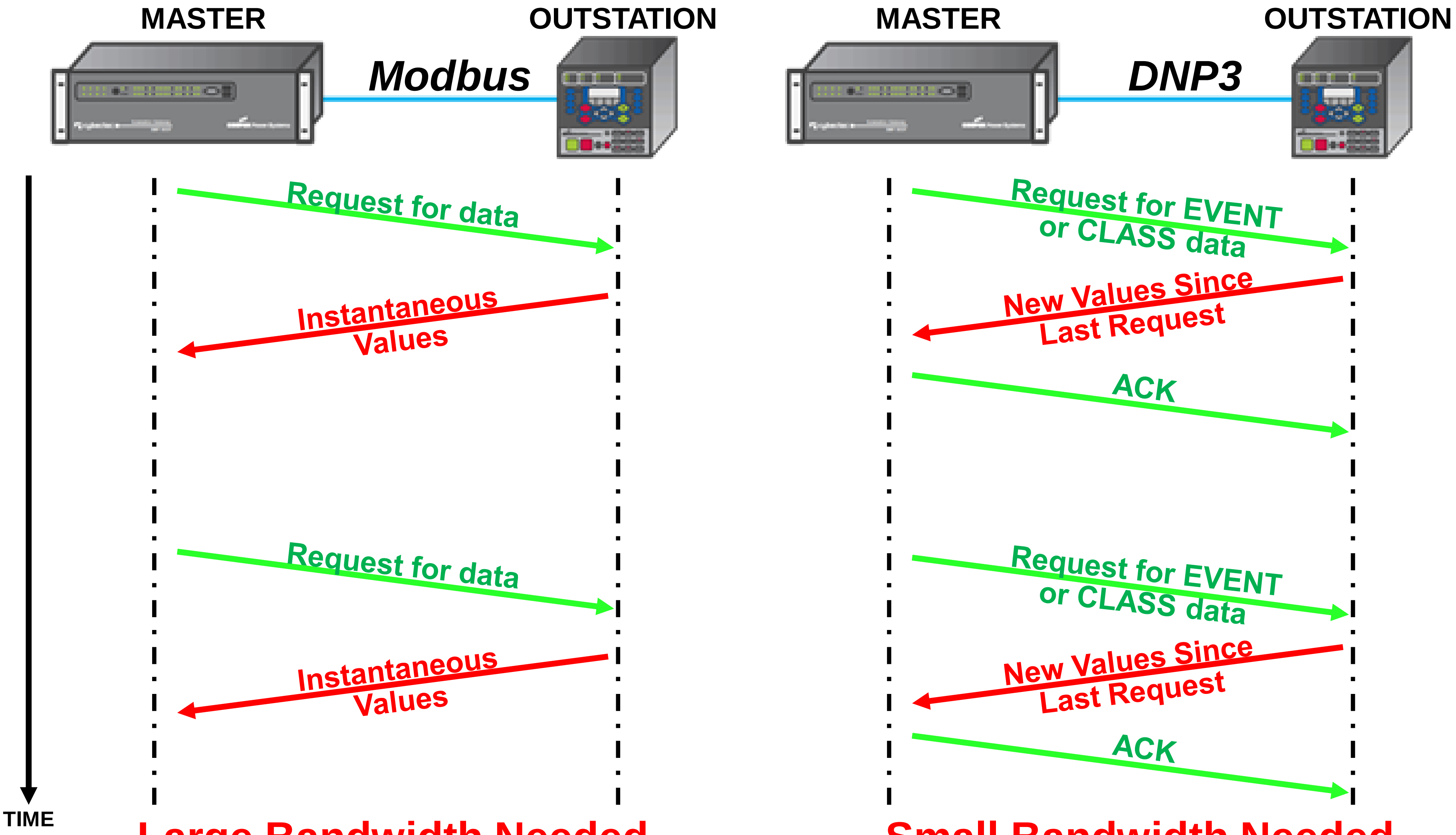
**The Outstation sends data according to its programmed default variation when the Master doesn't specify.**

# Default Variations: Programming the Outstation



| ***Action*** | ***Interpretation*** |
|---|---|
| Master requests information with a particular data format, i.e., a certain variation. | Outstation honors the request and sends information per the specified variation |
| Master requests information with **Variation=0**. | Outstation sends information per its default, programmed variation |
| Outstation sends unsolicited data, i.e., without a request from Master | Outstation sends information per its default, programmed variation |

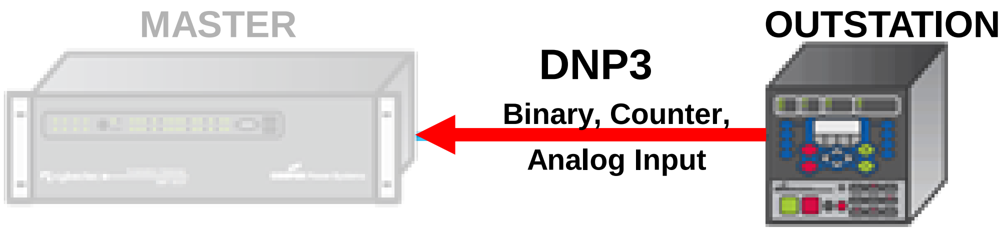
# Introducing Event (Change) Data with Classes



**Large Bandwidth Needed**

**Small Bandwidth Needed**

# Event CLASSES



MASTER

DNP3

Binary, Counter,

Analog Input

OUTSTATION

- Four Classes are possible
  - Class 0 — Think Modbus-type instantaneous, or “static” values
  - Class 1
  - Class 2
  - Class 3

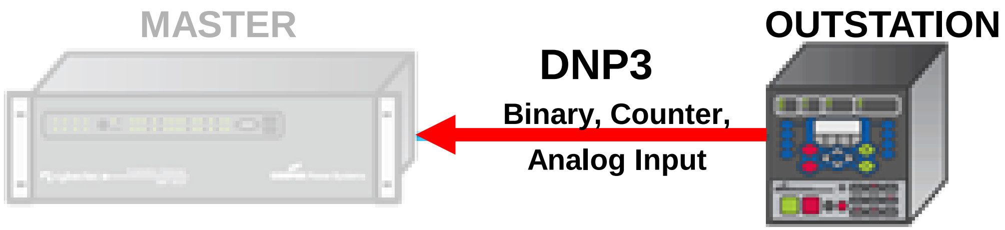
  Unique to DNP3: “event” or changed values

- Each input data point in the Outstation has a Class assignment
- Applies to Binary, Counter and Analog data INPUTS

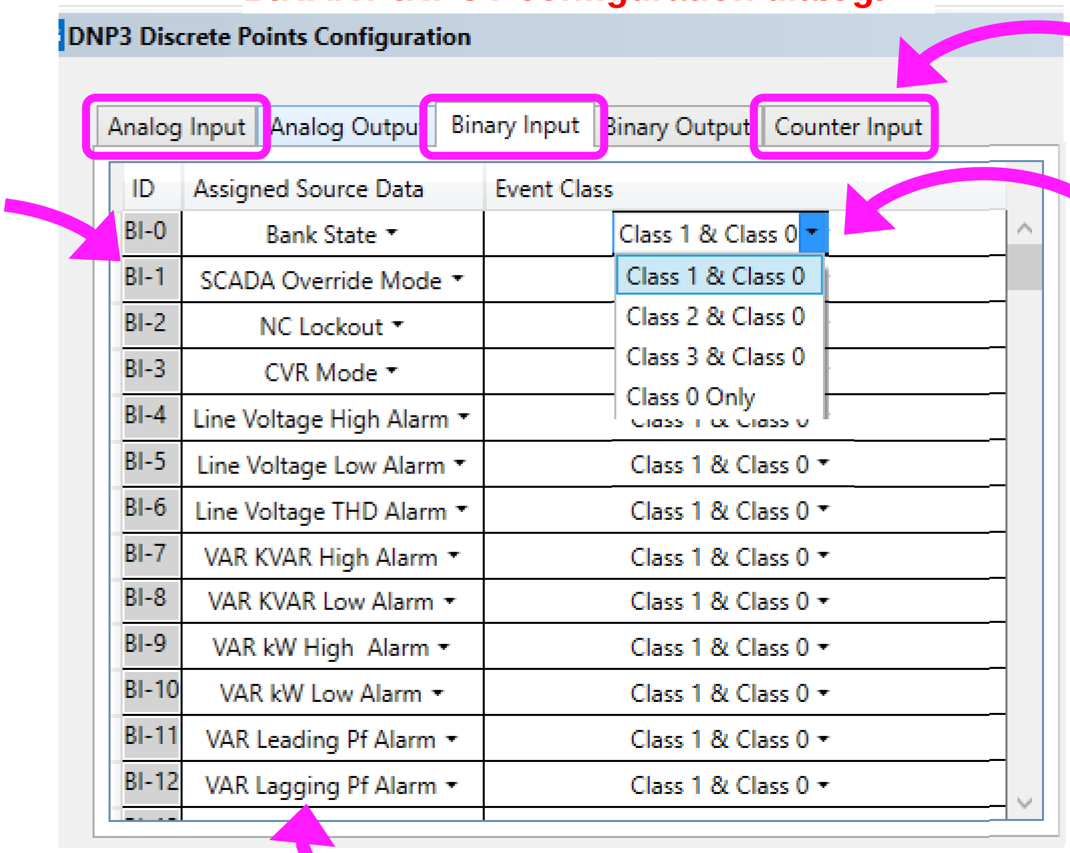
  (Analog and Binary OUTPUTs usually assigned to Class 0)

- Class assignments are Configurable in the Outstation

# Event CLASSES



**Example: portion of Outstation's BINARY INPUT configuration dialog.**



| ID | Assigned Source Data | Event Class |
|---|---|---|
| BI-0 | Bank State | Class 1 & Class 0 |
| BI-1 | SCADA Override Mode | |
| BI-2 | NC Lockout | |
| BI-3 | CVR Mode | |
| BI-4 | Line Voltage High Alarm | Class 1 & Class 0 |
| BI-5 | Line Voltage Low Alarm | Class 1 & Class 0 |
| BI-6 | Line Voltage THD Alarm | Class 1 & Class 0 |
| BI-7 | VAR KVAR High Alarm | Class 1 & Class 0 |
| BI-8 | VAR KVAR Low Alarm | Class 1 & Class 0 |
| BI-9 | VAR kW High Alarm | Class 1 & Class 0 |
| BI-10 | VAR kW Low Alarm | Class 1 & Class 0 |
| BI-11 | VAR Leading Pf Alarm | Class 1 & Class 0 |
| BI-12 | VAR Lagging Pf Alarm | Class 1 & Class 0 |

Class 1 & Class 0
Class 2 & Class 0
Class 3 & Class 0
Class 0 Only

**Index Number makes each Binary Input or point unique.**

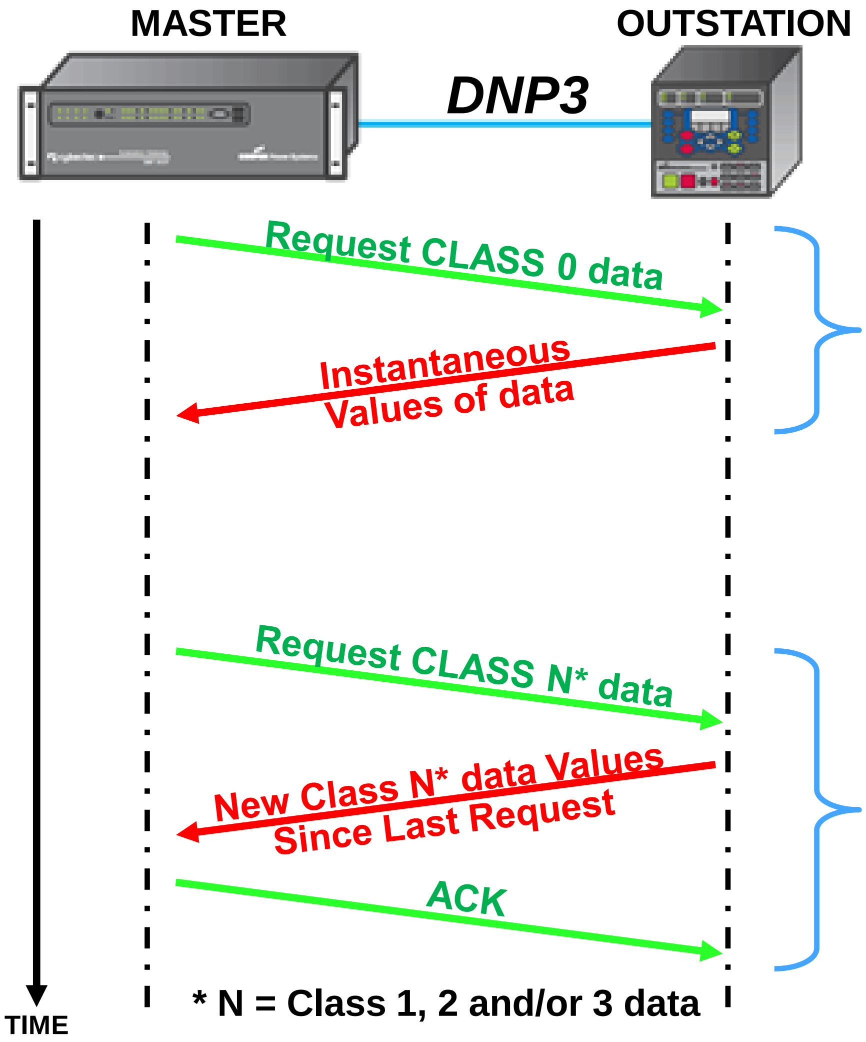
**Similar Class assignment for all Inputs**

**Class assigned to each point.**

**Particular signal assigned to each point.**

EATON
Powering Business Worldwide

# Requesting Event (Change) Data with Classes


MASTER
OUTSTATION
DNP3
Request CLASS 0 data
Instantaneous Values of data
Request CLASS N* data
New Class N* data Values Since Last Request
ACK
TIME

Static Data request similar to Modbus; perform rarely

Event Data requests for changes; perform frequently

* N = Class 1, 2 and/or 3 data

Powering Business Worldwide

# Event or Class Data Principles

- Also Knows as: Report By Exception (RBE)
  - Initial image of Outstation data is reported, i.e., Class 0
  - Thereafter only changes are reported, Class 1, 2, 3
  - Uses bandwidth efficiently
- Transfer of Event data is acknowledged

# RBE: Change Event Definition

- User-settable parameters in Outstation determine when an event occurs
- Binary
  - No parameter needed
  - A logic state change **0→1**, or **1→0** is an Event
- Counter
  - User determines unique Deadband **for each point**
  - Counter change exceeding the Deadband is an Event
- Analog
  - User determines unique Deadband or Hi/Low threshold **for each point**
  - Analog change exceeding deadband or threshold is an Event

# DNP3 Data Classes

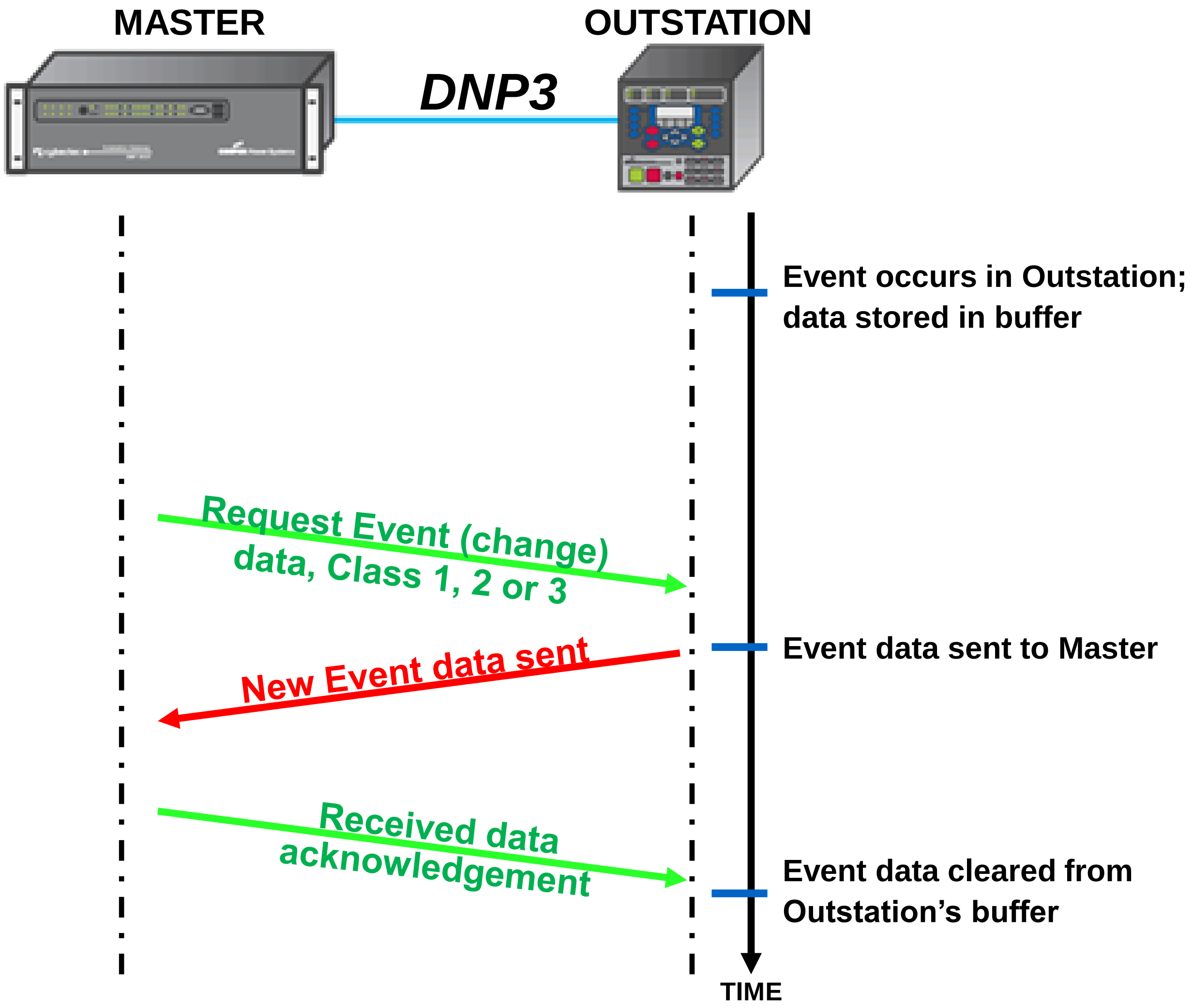
Static: CLASS 0

- The instantaneous value of
  Binary Status, Counter Value, Analog Value

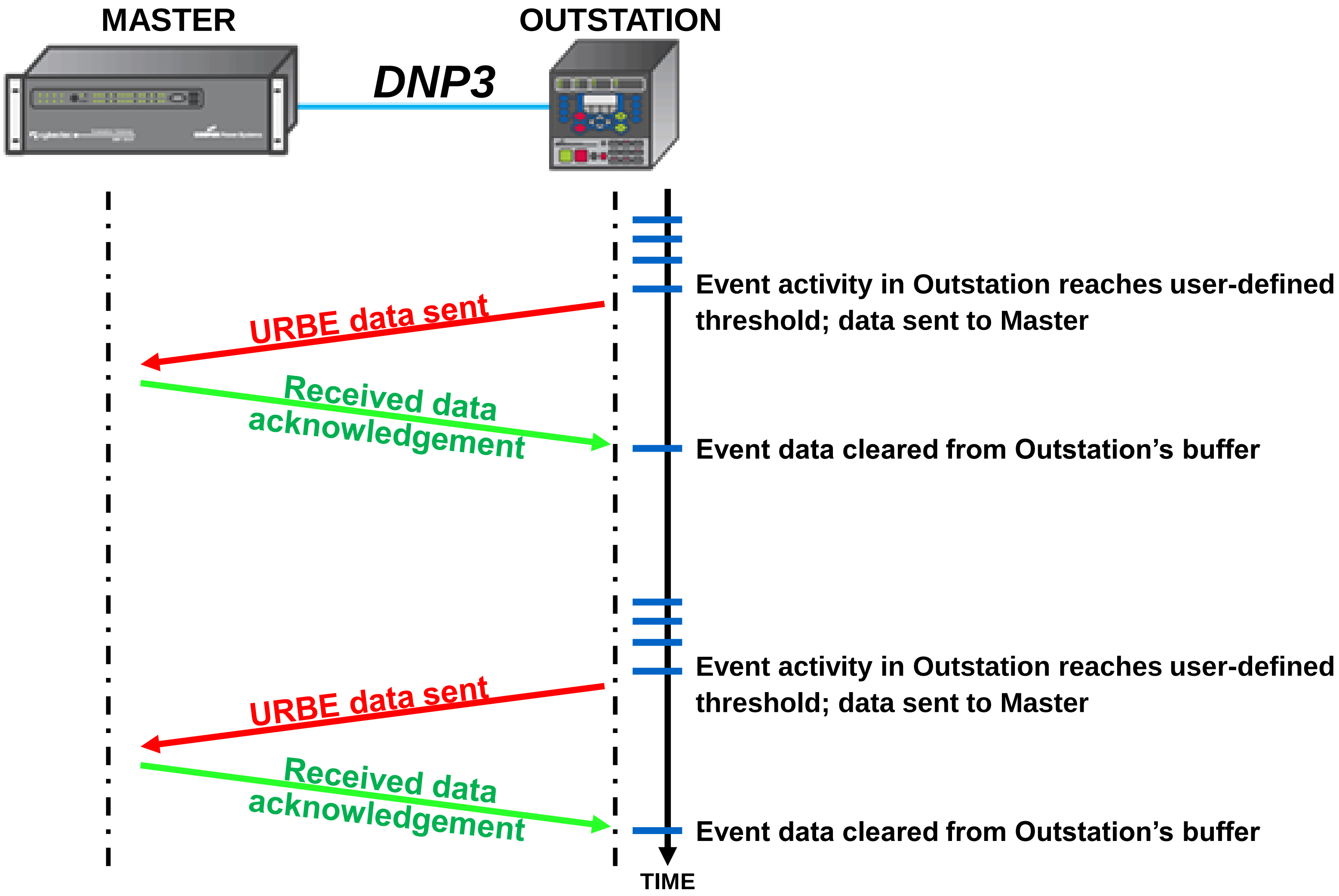
Event: CLASS 1, 2 or 3

- Change of Binary Status
- Change of Counter Value – defined by deadband setting
- Change of Analog Value – defined by deadband or high/low threshold settings

# Event Report By Exception (RBE)


MASTER
OUTSTATION
DNP3
Request Event (change) data, Class 1, 2 or 3
New Event data sent
Received data acknowledgement
Event occurs in Outstation; data stored in buffer
Event data sent to Master
Event data cleared from Outstation's buffer
TIME

# Unsolicited Report By Exception (URBE)



Event activity in Outstation reaches user-defined threshold; data sent to Master

Event data cleared from Outstation's buffer

Event activity in Outstation reaches user-defined threshold; data sent to Master

Event data cleared from Outstation's buffer

# Reporting Options

- DNP3 provides several means to retrieve data:
  - ***Polled static***: The master only polls for Class 0 data.
  - ***Polled Report-by-Exception***: The master frequently polls for event data, and occasionally for Class 0 data
  - ***Unsolicited Report-by-Exception***: Most communication is unsolicited, with an occasional integrity poll for Class 0 data
  - ***Quiescent***: The master never polls the slave, all communication is unsolicited report-by-exception

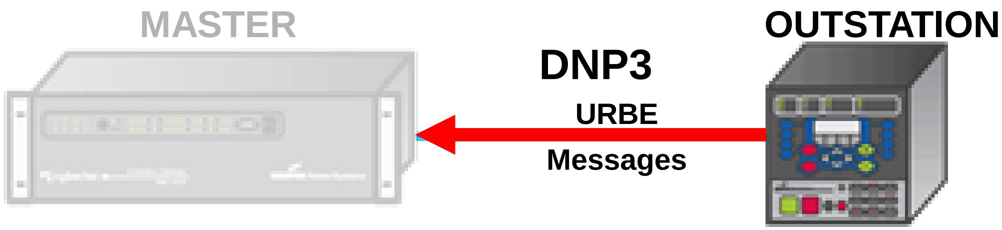
# **Unsolicited** Report By Exception (URBE)

- Outstation event activity triggers transmission of URBE message
- User-configurable parameters establish activity thresholds
- Class 1, 2, 3 Event Assignments used to prioritize critical vs. non-critical event activity

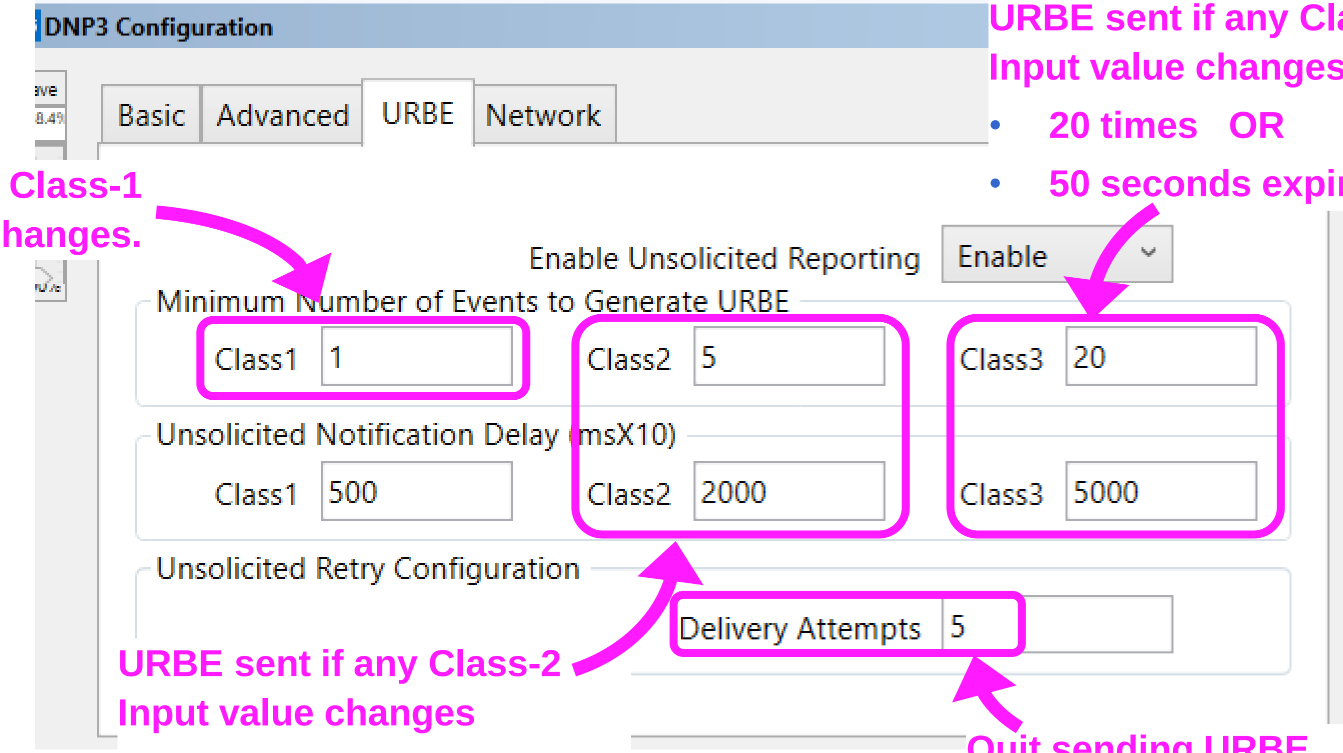
# RBE / URBE: Change Event Definition

- Same User-settable parameters in Outstation determine when an event occurs for RBE and URBE reporting
- Binary
  - No parameter needed
  - A logic state change **0→1**, or **1→0** is an Event
- Counter
  - User determines unique Deadband **for each point**
  - Counter change exceeding the Deadband is an Event
- Analog
  - User determines unique Deadband or Hi/Low threshold **for each point**
  - Analog change exceeding deadband or threshold is an Event

# URBE Config.



**Example: portion of Outstation's URBE configuration dialog.**



DNP3 Configuration

Enable Unsolicited Reporting: Enable

| | | | | | |
|---|---|---|---|---|---|
| Minimum Number of Events to Generate URBE | | | | | |
| Class1 | 1 | Class2 | 5 | Class3 | 20 |
| Unsolicited Notification Delay (msX10) | | | | | |
| Class1 | 500 | Class2 | 2000 | Class3 | 5000 |
| Unsolicited Retry Configuration | | | | | |
| Delivery Attempts | 5 | | | | |

URBE sent if any Class-1 Input value changes.

URBE sent if any Class-3 Input value changes

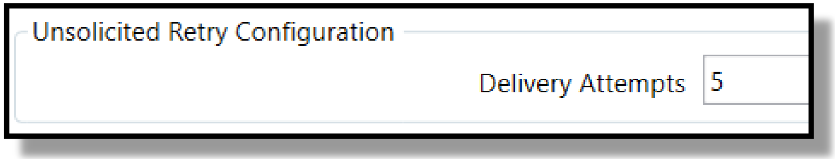
- 20 times OR
- 50 seconds expire

URBE sent if any Class-2 Input value changes

- 5 times OR
- 20 seconds expire

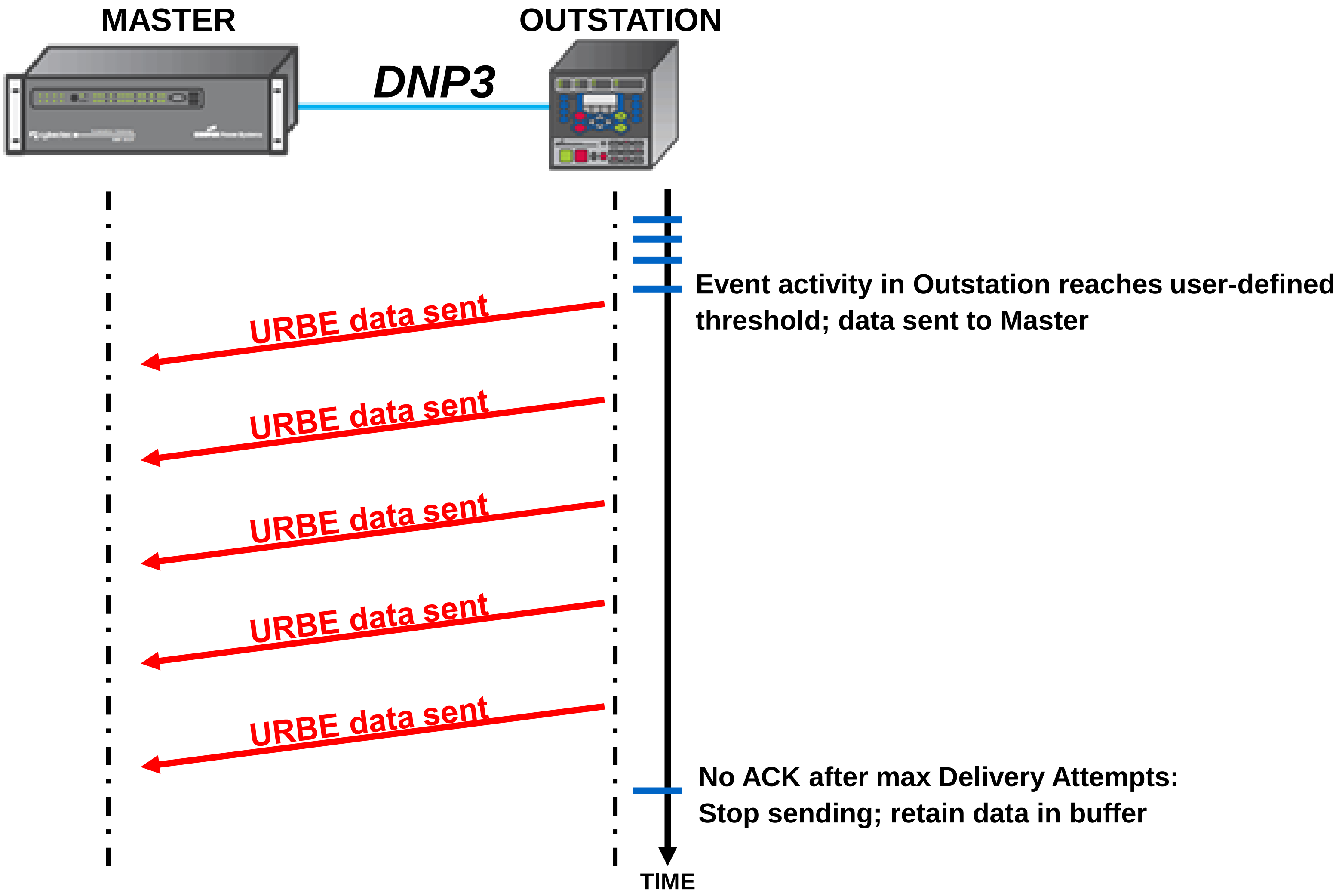
Quit sending URBE messages after 5 attempts unacknowledged

# URBE Delivery Attempts



Unsolicited Retry Configuration

Delivery Attempts: 5

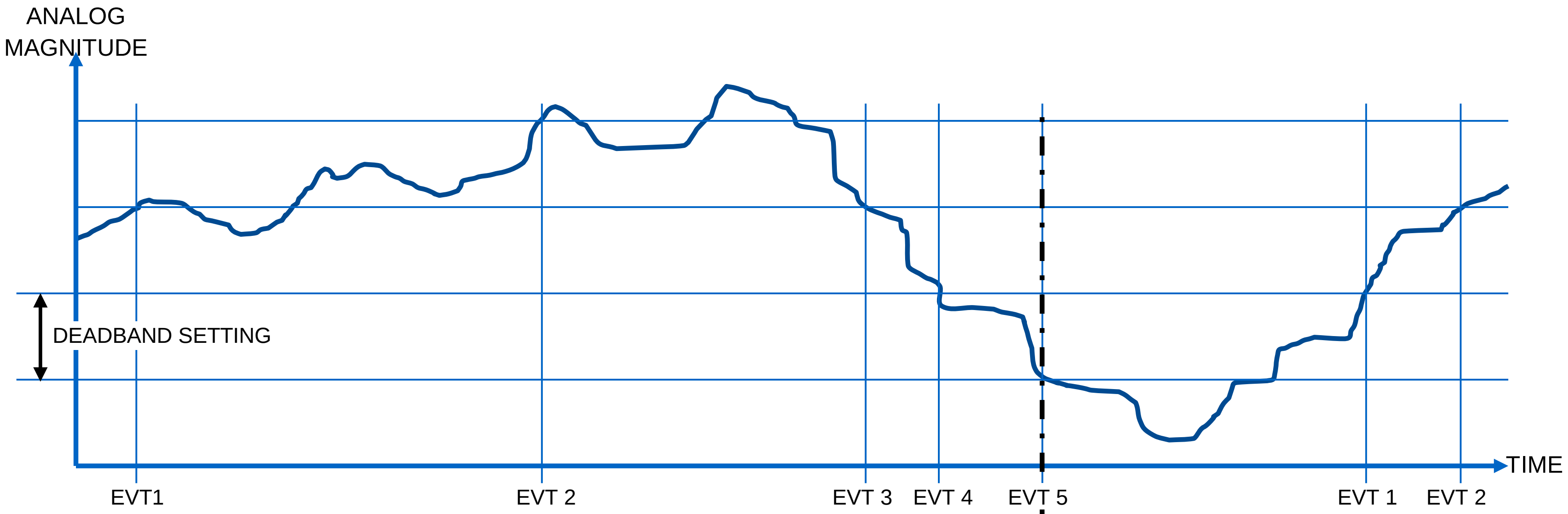


Event activity in Outstation reaches user-defined threshold; data sent to Master

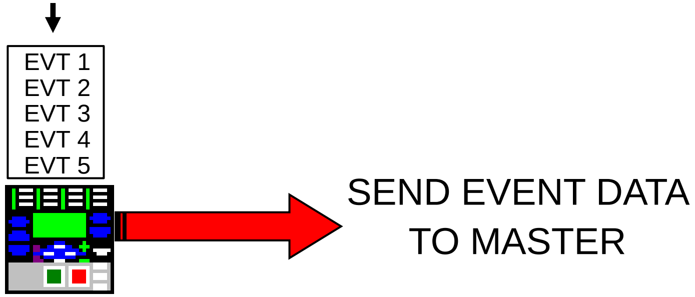
No ACK after max Delivery Attempts: Stop sending; retain data in buffer

# URBE: Unsolicited Report By Exception
## Analog Deadband

- # Events to Generate URBE = 5 (for the Class assignment of this analog)
- Unsolicited Notification Delay = ∞
- Deadband Setting (as shown)



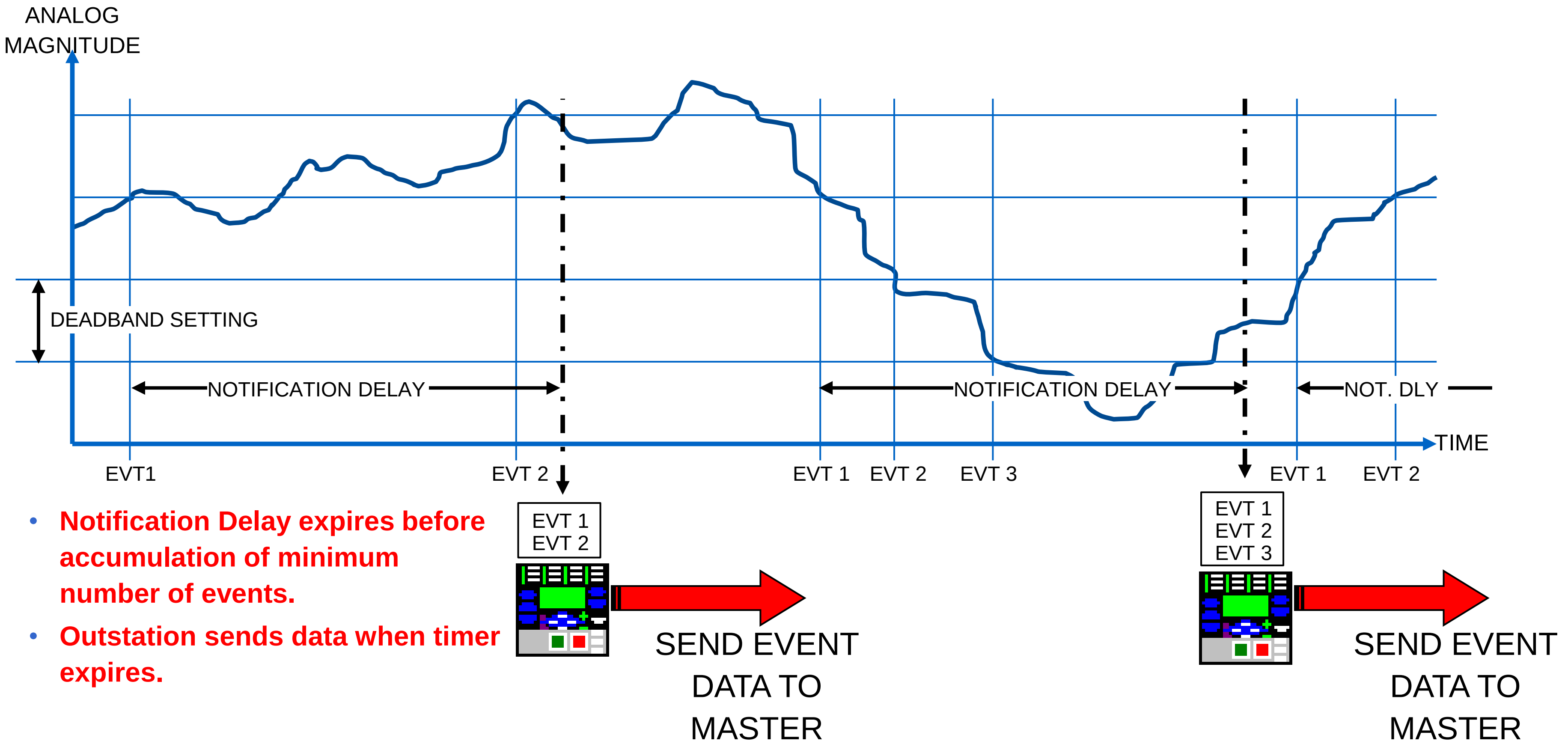
- **Analog magnitude change more than DEADBAND causes an event.**
- **Outstation sends data when # of events equals minimum value.**



# URBE: Unsolicited Report By Exception

## Analog Deadband

- # Events to Generate URBE = 5 (for the Class assignment of this analog)
- Unsolicited Notification Delay (as shown)
- Deadband Setting (as shown)

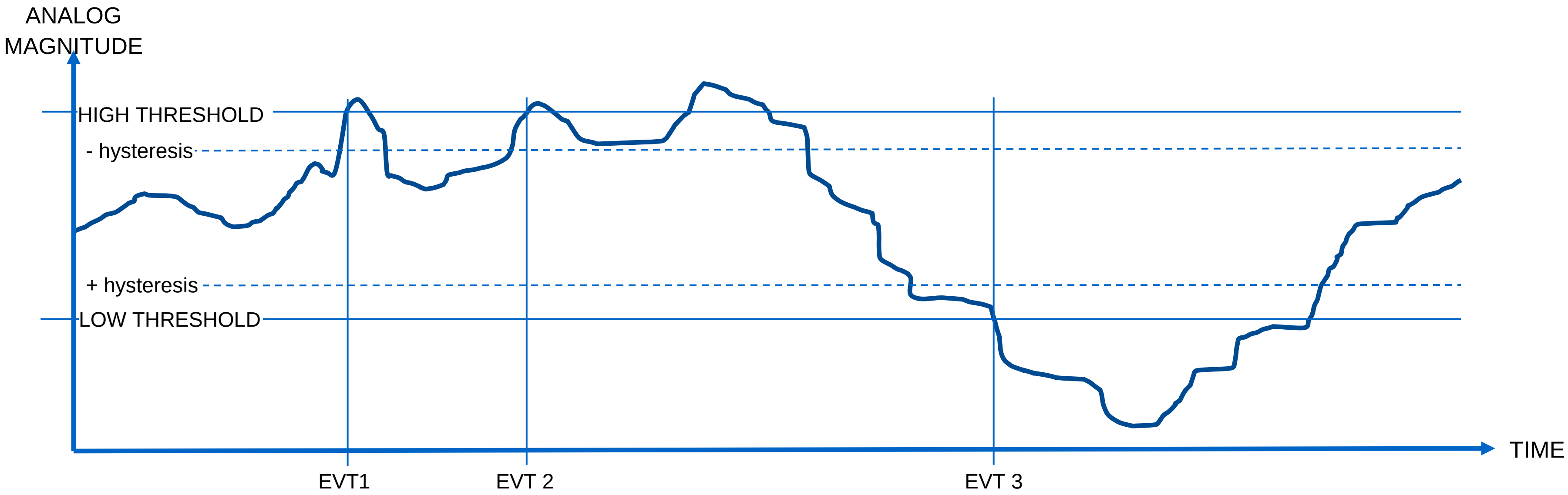


- **Notification Delay expires before accumulation of minimum number of events.**
- **Outstation sends data when timer expires.**

# URBE: Unsolicited Report By Exception

## Analog Hi, Low Thresholds

- # Events to Generate URBE = 5 (for the Class assignment of this analog)
- Unsolicited Notification Delay = ∞
- Threshold Settings (as shown)

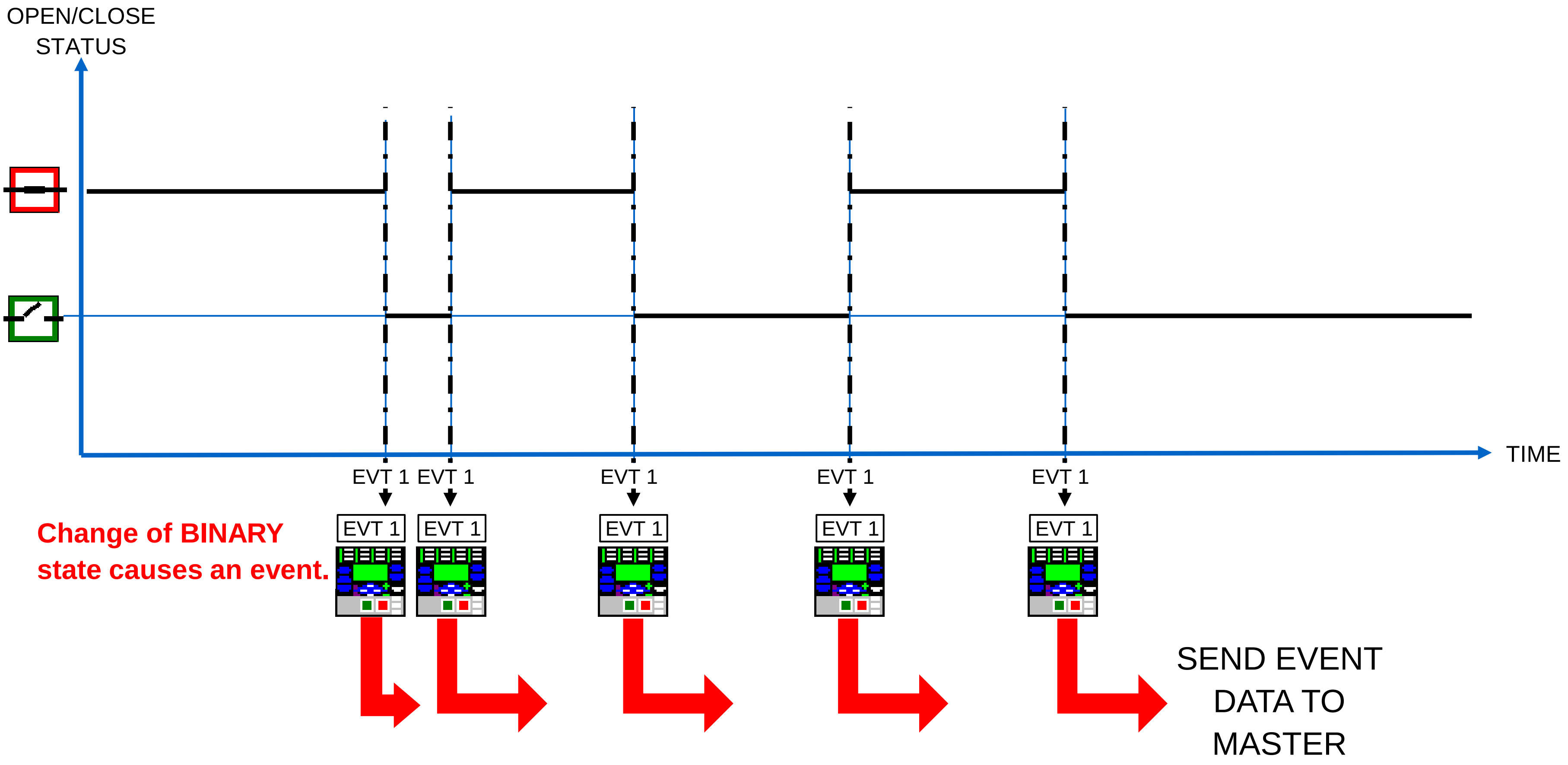


**Analog magnitude exceeding threshold causes an event.**

# URBE: Unsolicited Report By Exception

## Binary

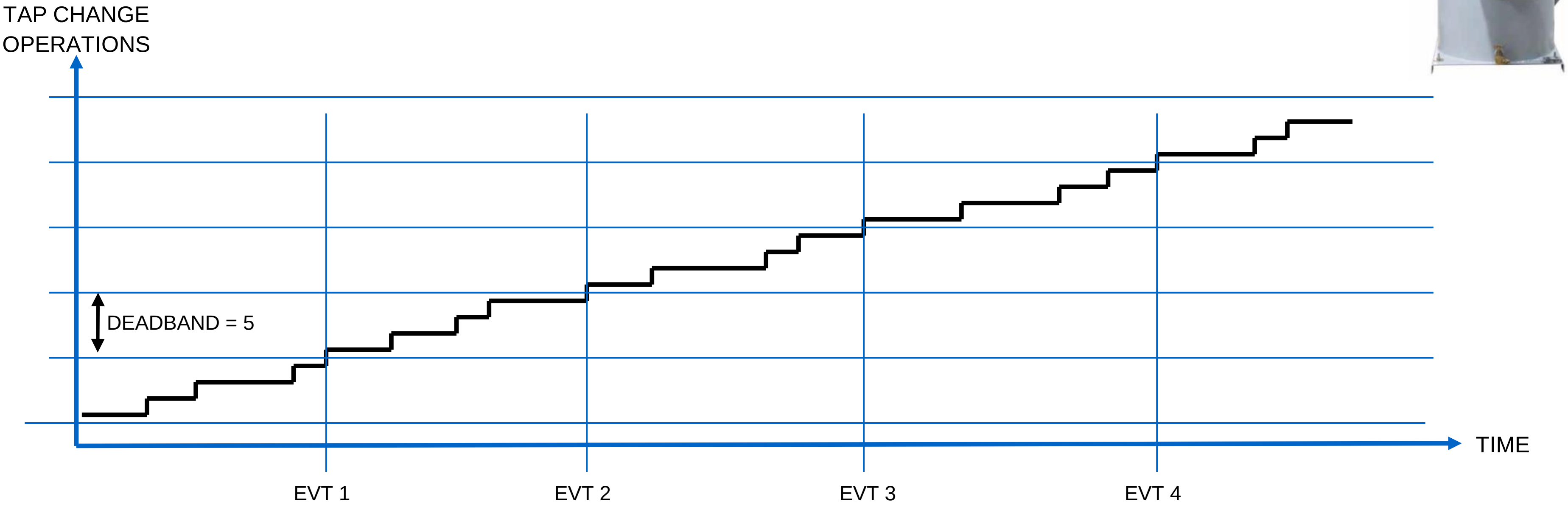
- # Events to Generate URBE = 1
- Unsolicited Notification Delay = don't care



# URBE: Unsolicited Report By Exception

## Integer: Counter

- # Events to Generate URBE = 15
- Unsolicited Notification Delay = ∞
- Deadband Setting = 5 counts



**Counter value change more than DEADBAND causes an event.**

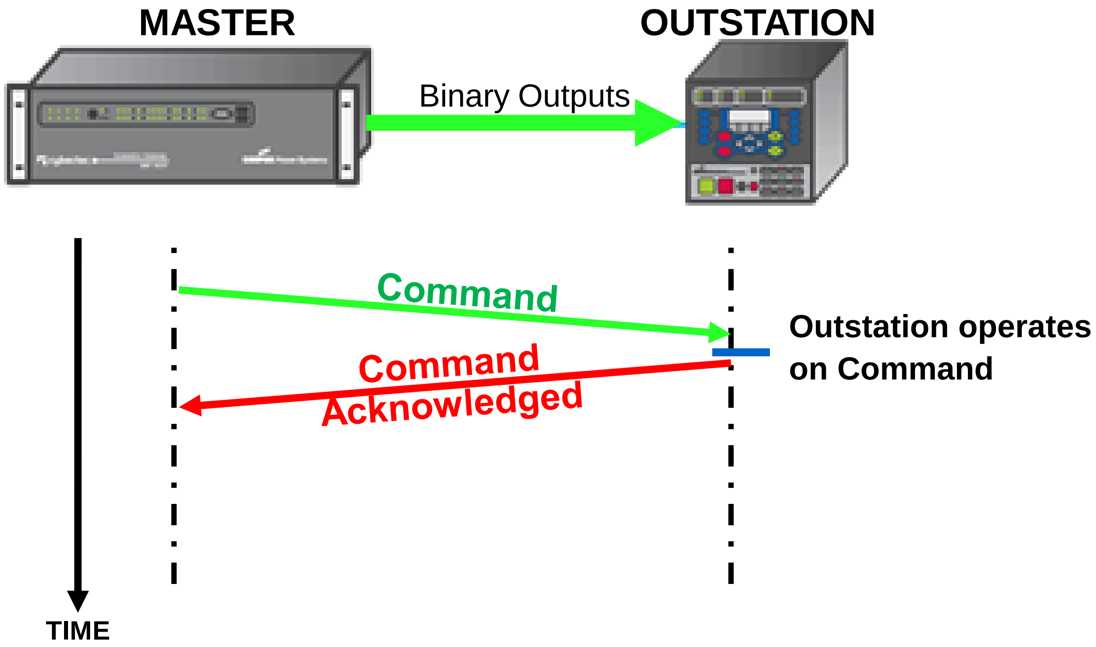
EATON
Powering Business Worldwide

# Control Commands: Binary Outputs

## Control Relay Output Block (CROB)

## Direct Operate

- Outstation immediately responds to Master's command
- Subject to incorrect commands due to communications errors



# Control Commands: Binary Outputs

## Control Relay Output Block (CROB)

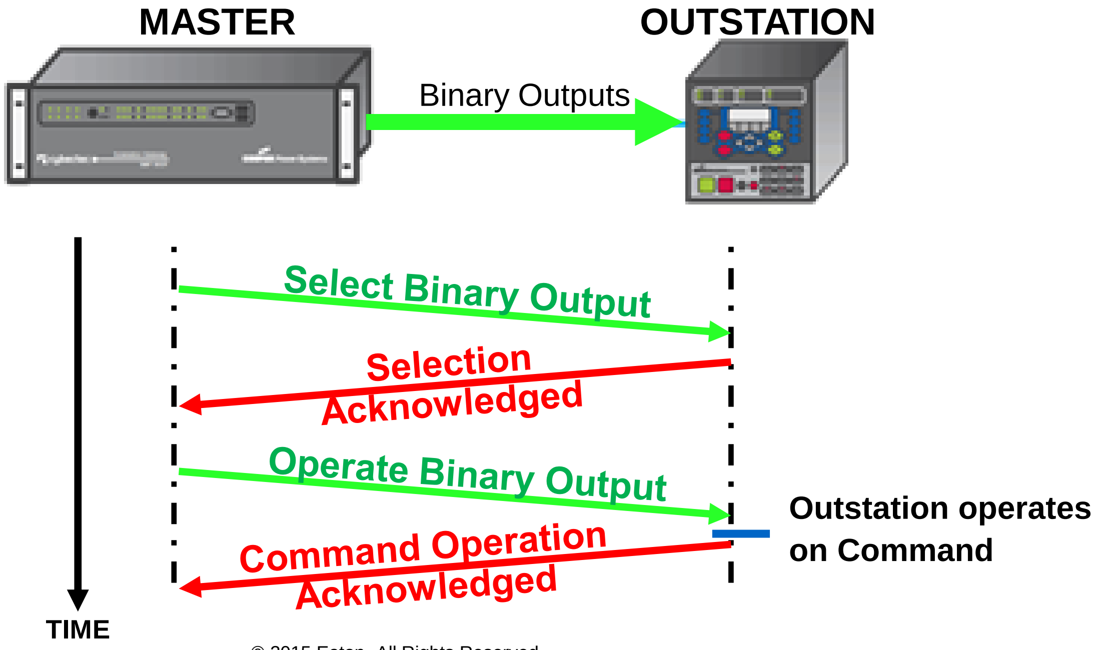
- The basic implementation permits:
  - **Trip/Close**. Single Point. Example: write ONE to CLOSE; write ZERO to OPEN
  - **Pulsed**. Single Point. Example: write ONE to enable Alt Profile; IED then self-resets point value to ZERO.
  - **Latch On/Latch Off**. Two Pulsed Points. Example: write ONE to turn a mode on; write ONE to other point to turn mode off.
- The master is required to be configurable to match the outstation’s requirements

# Control Commands: Binary Outputs

## Control Relay Output Block (CROB)

### Select Before Operate

- Master Selects an output, and Outstation responds
- Master receives response and verifies it is correct
- Master issues Operate command, and the Outstation honours the command after verifying that the Select and Operate commands match

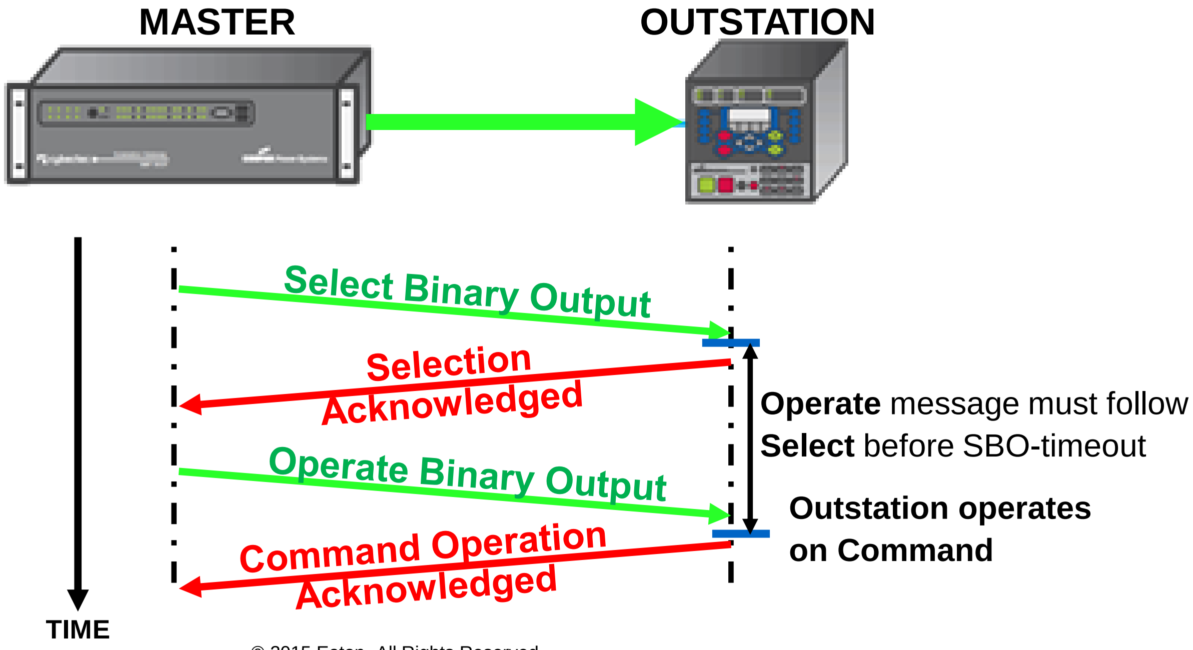


# Control Commands: Binary Outputs

## Control Relay Output Block (CROB)

## Select Before Operate: Benefit

- Two-pass operation increases integrity.
- Provides immunity due to communication errors.
- SBO Timeout in Outstation ignores latent Commands from Master



MASTER

OUTSTATION

Select Binary Output

Selection Acknowledged

**Operate** message must follow **Select** before SBO-timeout

Operate Binary Output

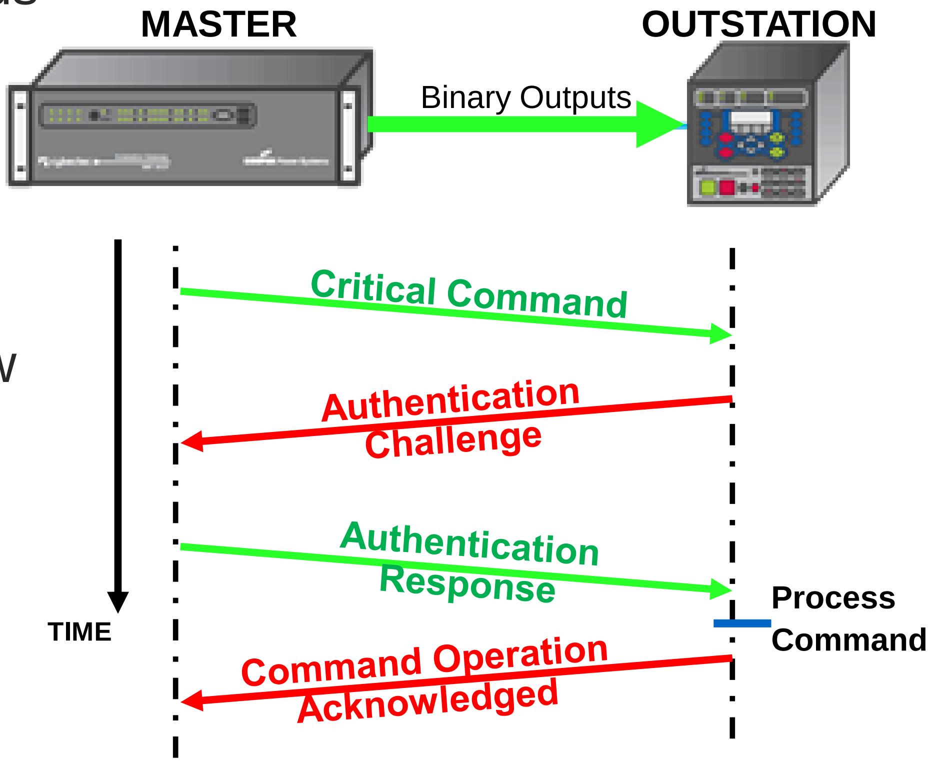
**Outstation operates on Command**

Command Operation Acknowledged

TIME

# DNP3 SAv5: Secure Authentication v5

- Mechanism to authenticate both ends of a DNP3 communication link and ensure data integrity of critical messages
- Data not encrypted
- Relatively lightweight; works on slow networks
- Independent of transport; use with serial or network communications



# DNP3 Subset, i.e., Levels

- Subset Levels provide a way for DNP3 to identify commonly used sets of Object Groups and functions
  - Level-1: describes a minimum subset of the protocol typically between Master and IED.
  - Level-2: slightly larger than Level-1;
    Master and large IED or small RTU
  - Level-3: larger than Level-2; Master and advanced RTU
  - Level-4: larger than Level-3

Basic SCADA Operation achieved with Level-1 functions

***Reference:***

IEEE Std 1815-2012

IEEE Standard for Electric Power Systems Communications—Distributed Network Protocol (DNP3)

# DNP3 Internal Indications

## Internal Indication Bits; IIN

- Two, eight-bit Octets
- Contains information about the Outstation
- Part of Application Layer

| Least Significant Bit: IIN 1 | |
|---|---|
| **Bit** | **Function** |
| 0 | All Stations Message Received |
| 1 | Class 1 Data Available |
| 2 | Class 2 Data Available |
| 3 | Class 3 Data Available |
| 4 | Time sync required from Master |
| 5 | Outstation is in LOCAL |
| 6 | Device Trouble |
| 7 | Device Restart |

# DNP3 Internal Indications

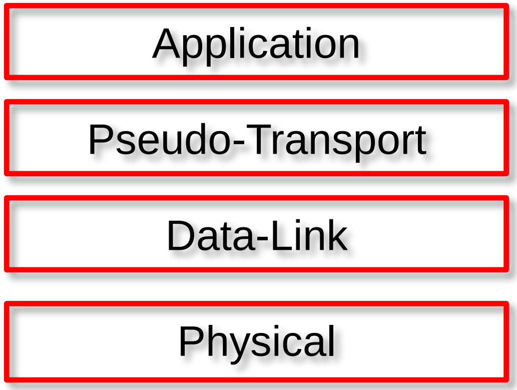
## Internal Indication Bits; IIN

- Contains information about the Outstation
- Part of Application Layer

| Least Significant Bit: IIN 2 | |
|---|---|
| **Bit** | **Function** |
| 0 | Not supported |
| 1 | Requested Objects are Unknown |
| 2 | Parameters in qualifier or data fields invalid or out-of-range |
| 3 | Event Buffer OVERFLOW |
| 4 | Request understood but already executing |
| 5 | Current configuration is corrupted |
| 6 | Reserved |
| 7 | Reserved |

# DNP3 Layers

- DNP3 is a layered protocol
- ~~OSI (Open System Interconnection) 7 Layer protocol~~
- DNP3 adheres to a simplified 3 layer standard proposed by the IEC called Enhanced Performance Architecture, or EPA
- DNP3 expands EPA by adding a fourth layer, a pseudo-transport layer that allows for message segmentation



Application

Pseudo-Transport

Data-Link

Physical

# DNP3 Layers

| | |
|---|---|
| Application | **Object groups, variations, classes, IIN bits** |
| Pseudo-Transport | **Message segmentation; sequence numbering; dropped frame detection** |
| Data-Link | **Manages logical link; improves error characteristics; CRC check** |
| Physical | **RS-232; RS-485; Ethernet, voltage changes on the wire** |

EATON

Powering Business Worldwide