DNP3 with Campbell Scientific Dataloggers

What is DNP3?

DNP3 (Distributed Network Protocol) is designed to optimize transmission of data and control commands from a master computer to one or more remote devices or outstations. DNP3 is an open standard developed by Westronic, Inc. for use in SCADA applications. It is non-proprietary and is available at www.dnp.org.

In the context of Campbell Scientific instrumentation, a remote device or outstation is one of the following dataloggers:

- CR6 Series
- CR800 Series
- CR1000
- CR3000

Features

Following are principle features of DNP3:

- Standardized protocol to ensure interoperability among vendors.

- Efficient use of bandwidth through RBE (Report By Exception). Only a change in data (an Event) is reported rather than reporting all data each time a device is polled. RBE is a principle reason for the success of DNP3.

- Allows a Campbell Scientific datalogger, via Unsolicited Responses, to transmit events without first receiving a request.

- Provides a high degree of reliability through communication layers, which provide an organized scheme for data and control data transmissions in an organized manner.

- Minimizes the impact of noise and signal distortion on communication circuits.

Implementation

Terms

static data

Current values of data points at the instant they are transmitted. Examples include On or Off state of a bi-state device, or a temperature or water-level value.
event

The crossing of a threshold by an analog value, or the switch of a binary input. For example, an event occurs when an analog value changes by more than the configured dead-band or threshold, or when a binary input changes from On to Off.

An event can be recorded with or without a timestamp. Timestamps enable the master to generate time-sequence reports.

Event data are kept in the datalogger until confirmation has been received from the master that the data are received. In other words, event data will not be discarded until after the datalogger receives confirmation that the master has received the data.

variations

Data format. For example, static data may be presented as 16-bit or 32-bit integers, or as 16-bit or 32-bit floating-point values. These data may or may not include a flag to indicate if the source is online. Event data can be represented in the same formats as static data, but also have additional variations to allow for timestamps.

objects

The bits and bytes for each index point in a message. A sending device must format data for parsing and interpretation by the receiving device. Objects do the following:

- differentiate between static and event data
- distinguish among data types, such as the following:
  - counters
  - binary or analog inputs
  - binary or analog outputs
  - control commands

The format of an object is determined by group and variation number. For simplicity, the Campbell Scientific DNP3 implementation does not refer to groups since the object includes both group number and variation.

class

DNP3 has four classes of data. Static data are Class 0. Event data are Class 1, Class 2, and Class 3, with no logical differentiation between these classes. Originally, Class 1 events were higher priority than Class 2, and Class 2 higher than Class 3. However, in current applications, DNP3 allows you to organize classes in the strategy that works best for your application. By way of analogy, for those familiar with CRBasic data classification, Class 0 holds current points in time similar to the Public table. Classes 1, 2, and 3 hold event history similar to user-defined final-memory data tables.
CRBasic Programming Language

DNP3 is implemented in Campbell Scientific dataloggers through a program you write in CRBasic. CRBasic is a programming language similar to BASIC. Programs are written with CRBasic Editor, which is part of LoggerNet datalogger support software.

The following CRBasic instructions implement DNP3:

- DNP()
- DNPUpdate()
- DNPVariable()

Each instruction is discussed in the following sections with sufficient detail to aid in a basic understanding of the Campbell Scientific implementation. Additional resources are available in CRBasic Editor Help and the corresponding datalogger operator’s manual.

DNP() Instruction

DNP(ComPort, BaudRate, Confirmation, TimeOffset(opt), MaxTimeDiff(opt), DNPTLS)

DNP() programs a Campbell Scientific datalogger as a remote device or outstation. It is executed once and is usually placed between the BeginProg and Scan() statements. See CRBasic Example 16, Complete Program for a Sample Application (p. 10), for an example of placement.

ComPort and BaudRate specify the datalogger communication port and baud rate with which to communicate with the master.

Confirmation determines whether data-link-layer confirmation (DLLC) is enabled. It also sets the timeout interval for data-link-layer and application-layer confirmation.

DLLC requires extra time for sending and receiving confirmation messages and for waiting on multiple timeouts if retries are configured. It is always disabled for a TCP/IP link. In most cases, DLLC is considered redundant because the datalogger will always use a higher-level application layer confirmation when transmitting event data or multi-fragment responses. The confirmation parameter is entered in the form of XSSS. X = 0 enables DLLC. X = 1 disables. SSS is the number of seconds the datalogger will wait for a response to DLLC or application-layer confirmation before timing out.

TimeOffset and MaxTimeDiff (optional) keep the datalogger clock set to local time when the DNP3 master is sending time-synchronization commands to the datalogger.

DNPTLS is optional and available only with a CR6 datalogger programmed to enable TLS (Transport Layer Security). If the parameter is set to 0 or is omitted, TLS is disabled. If the parameter is set to 1, TLS is enabled. On account of slower processor speeds, DNPTLS is not available in CR800, CR1000, or CR3000 dataloggers.
## DNP() Examples

### CRBasic Example 1. DNP() Code Snip: Using TCP/IP for the DNP Port

```cr
'DTo use TCP/IP for the DNP port, set COMPort to 20000.  20000 is the
'default port number for DNP over TCP.  This port number must match in the master.
'DNP(ComPort, Baudrate, Confirmation, TimeOffset(opt), MaxTimeDiff(opt), DNPTLS)
DNP(20000,115200,1000)  'Use IP for communication port, confirmation disabled
```

### CRBasic Example 2. DNP() Code Snip: Using RS-232 Port for the DNP Port

```cr
'DTo use the nine-pin RS-232 port for DNP, set the COMPort to COMRS232.
'DNP(ComPort, Baudrate, Confirmation, TimeOffset(opt), MaxTimeDiff(opt), DNPTLS)
DNP(COMRS232,115200,1000)  'Baud rate 115200, confirmation disabled
```

### CRBasic Example 3. DNP() Code Snip: Using Data Link Layer and Application Confirmations

```cr
'DTo enable data link layer confirmation and set the application confirmation
'to 10 seconds, set Confirmation to 0010.
'DNP(ComPort, Baudrate, Confirmation, TimeOffset(opt), MaxTimeDiff(opt), DNPTLS)
DNP(COMRS232,115200,0010)  'Baud rate 115200, confirmation enabled
```

**NOTE** The use of data-link-layer confirmation (DLLC) is not recommended for most applications. See previous description of Confirmation parameter.

### CRBasic Example 4. DNP() Code Snip: Setting Local Time Offset

```cr
'DTo set a local-time offset of –1 hour, set the TimeOffset to 3600.  This
'value, in seconds, will be subtracted from local time for DNP objects and variations
'that return time.
'DNP(ComPort, Baudrate, Confirmation, TimeOffset(opt), MaxTimeDiff(opt), DNPTLS)
DNP(COMSDC7,115200,1000,3600,-1)  'DNP over SDC7, confirmation disabled, local-
time offset of 1 hr, ignore time-
synchronization commands from the master
```

**NOTE** If the datalogger is connected to both a DNP3 master and a LoggerNet datalogger support software server, a -1 for the MaxTimeDiff parameter can be entered to avoid problems that arise from a DNP3 master and a LoggerNet server both attempting to set the datalogger clock.

### CRBasic Example 5. DNP() Code Snip: Enabling TLS on the DNP TCP/IP Port (CR6 Only)

```cr
'DTo enable TLS on a TCP/IP
'DNP(ComPort, Baudrate, Confirmation, TimeOffset(opt), MaxTimeDiff(opt), DNPTLS)
DNP(20000,115200,1000,0,0,1)  'DNP over IP; TLS enabled
```
DNPVariable() Instruction

DNPVariable (Source, Swath, DNObject, DNPVariation, DNPClass, DNPFlag, DNPEvent, DNPNumEvents)

DNPVariable() configures DNP3 data for collection and transmission. For example, it can determine whether only static data or event data are collected. This instruction is usually executed only once for each data type. It typically is inserted between the BeginProg and Scan() instructions. See CRBasic Example 16, Complete Program for a Sample Application (p. 10), for an example of placement. Multiple DNPVariable() instructions are used in programs to configured for multiple data types.

**Source** is a variable array that specifies the source of data that will populate the DNP datalogger CRBasic array. **Source** variable array declarations:

- For Analog Input objects, declare CRBasic array As Long (integer). If object variation is single-precision floating point, however, declare array As FLOAT.
- For Analog Output objects, declare array As Long. If object variation is single-precision floating point, declare As FLOAT.
- For Binary Input objects, declare As BOOLEAN
- For Binary Output objects, declare As BOOLEAN

**Swath** must be smaller than or equal to the declared size of the **Source** variable array.

**DNObject** and **DNPVariation** parameters specify object and variation.

**DNPClass** specifies a classification strategy for different object types (Class 0, 1, 2, or 3).

**DNFlag** controls data quality flags for variations that include flags.

**DNPEvent** sets thresholds that constitute a change event.

**DNPNumEvents** specifies how many events are stored in history before they are sent to a master. It is equivalent to the event buffer size.

**DNPVariable() Examples**

*Data type storage and event buffer*

These examples store different data types and specify the size of an event buffer in the datalogger by specifying different DNP objects and variations. For a complete list of supported objects and variations, see CRBasic Help for the DNPVariable() instruction.
CRBasic Example 6. DNPVariable() Code Snip: Populating Static Analog Input Data Points

'Populate four static analog-input data points to a variable named Array_1().
'NOTE Array size is declared equal to or larger than Swath parameter.
'NOTE Class 0 is used for static data.
Public Array_1(4) as Long
'...
'DNPVariable (Source, Swath, DNPObj, DNPPar, DNPClass, DNPFlag, DNPEvent, DNPNumEvents)
DNPVariable (Array_1(),4,30,1,0,0,0,0) 'Object 30 variation 1 = static 32-bit analog input.

CRBasic Example 7. DNPVariable() Code Snip: Populating Analog Events

'Populate four 32-bit analog events to the variable Array_1().
'Keep 100 events in history (100 events for each point)
'NOTE Must specify object 30 before using object 32 to store event data.
'NOTE Must use Class 1, 2, or 3 to store event history.
Public Array_1(4) as Long
'...
'DNPVariable (Source, Swath, DNPObj, DNPPar, DNPClass, DNPFlag, DNPEvent, DNPNumEvents)
DNPVariable (Array_1(),4,32,1,1,0,0,100) 'Object 32 variation 1 = 32-bit analog change event without time.

CRBasic Example 8. DNPVariable() Code Snip: Populating Analog Input Events

'Populate four analog-input events as single-precision floating-point values with time.
'Keep 10 events in history.
Public Array_1(4) as Float
'...
'DNPVariable (Source, Swath, DNPObj, DNPPar, DNPClass, DNPFlag, DNPEvent, DNPNumEvents)
DNPVariable (Array_1(),4,32,7,1,0,0,10) 'Object 32 variation 7

CRBasic Example 9. DNPVariable() Code Snip: Populating Static Binary Input Points

'Populate 10 static binary input points to a variable named Binput()
Public Binput(10) as Boolean
'...
'DNPVariable (Source, Swath, DNPObj, DNPPar, DNPClass, DNPFlag, DNPEvent, DNPNumEvents)
DNPVariable (Binput(),10,1,2,0,0,0,0) 'Must assign object 1 before using object 2

Setting attributes of data values

Many readable DNP3 data objects have variations that include flags consisting of bit-string fields to indicate conditions or attributes of the associated data value. The DNPFlag parameter sets associated data values to online, offline, or online and restart. Following is an example.
Defining an event

By default, any change, no matter how small, is an event. However, you can use the \texttt{DNPEvent} parameter to limit the changes that are considered events. CRBasic Example 11 defines a Boolean variable as a trigger with \texttt{DNPEvent} and uses logic to define an event.

CRBasic Example 11. Complete Program: Conditional Storage of an Event

\begin{verbatim}
'Only store an event if a counter is greater than or equal to 5
Public Array(4) As Long
Public Counter As Long
Public Trigger As Boolean

BeginProg
DNP(20000,115200,1000)  'Use IP for comport, confirmation disabled
DNPVariable(Array(),4,30,1,0,0,0,0)  'static analog data
'DNPVariable(Array(),4,32,1,1,0,trigger,10)  'event analog data
Scan(1,Sec,1,0)  'scan
counter = counter +1
Array()= counter
If Counter>=5 Then Trigger=1 Else Trigger=0
If Counter =10 Then Counter = 0  'reset counter to 0 at 10

'Data storage
DNPUpdate(1,10)  'slave, master
NextScan
EndProg
\end{verbatim}

DNPUpdate() Instruction

\begin{verbatim}
DNPUpdate (DNPSlaveAddr, DNPMasterAddr, UnsolicitedResponseTimeout(opt), UnsolicitedResponseRetries(opt), MasterConnectionHandle(opt))
\end{verbatim}

\texttt{DNPUpdate()} is analogous to the CRBasic \texttt{CallTable()} instruction. It enables a datalogger to update the DNP array with new values. No data will be written to the DNP data array until \texttt{DNPUpdate()} is run. For this reason, \texttt{DNPUpdate()} is placed inside a \texttt{Scan/NextScan} structure after the elements of the DNP array that are to be updated.

\texttt{DNPSlaveAddr} assigns a DNP address to the datalogger.
**DNPMasterAddr** specifies the addresses of masters the datalogger will respond to. Communications with up to three masters are supported. A separate **DNPUpdate()** instruction is required for each master.

### Examples

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</tr>
<tr>
<td>'Variables for Measurements</td>
</tr>
<tr>
<td>Public BattV</td>
</tr>
<tr>
<td>Public PTemp</td>
</tr>
<tr>
<td>'Declare Units for measurements</td>
</tr>
<tr>
<td>Units BattV = Volts</td>
</tr>
<tr>
<td>Units PTemp = Deg C</td>
</tr>
<tr>
<td>'Variable declarations for DNP3</td>
</tr>
<tr>
<td>Dim Analog_Inputs(2) As Long</td>
</tr>
<tr>
<td>Dim Analog_Inputs_Flag(2) As Long</td>
</tr>
<tr>
<td>'Data Table To Record 10-Minute Averaged Measurements</td>
</tr>
<tr>
<td>DataTable(TenMin,True,-1)</td>
</tr>
<tr>
<td>DataInterval(0,10,Min,10)</td>
</tr>
<tr>
<td>Minimum(1,BattV,FP2,False,False)</td>
</tr>
<tr>
<td>Average(1,PTemp,FP2,False)</td>
</tr>
<tr>
<td>EndTable</td>
</tr>
<tr>
<td>'Main Program</td>
</tr>
<tr>
<td>BeginProg</td>
</tr>
<tr>
<td>'Set up Datalogger as DNP3 outstation</td>
</tr>
<tr>
<td>DNP (20000,115200,1000) 'Set up comm port</td>
</tr>
<tr>
<td>DNPVariable (Analog_Inputs(),2,30,2,0,0,0,0) 'Static data</td>
</tr>
<tr>
<td>DNPVariable (Analog_Inputs(),2,32,2,1,0,0,120) 'Event data, 120 point buffer, any change, all events are 'class 1</td>
</tr>
<tr>
<td>Scan (1,Sec,0)</td>
</tr>
<tr>
<td>PanelTemp (PTemp,250)</td>
</tr>
<tr>
<td>Battery (BattV)</td>
</tr>
<tr>
<td>'Update DNP3 Analog Inputs</td>
</tr>
<tr>
<td>Analog_Inputs(1) = BattV *10</td>
</tr>
<tr>
<td>Analog_Inputs(2) = PTemp *10</td>
</tr>
<tr>
<td>DNPUpdate (1,103) 'slave 1, master 103</td>
</tr>
<tr>
<td>DNPUpdate (1,104) 'slave 1, master 104</td>
</tr>
<tr>
<td>DNPUpdate (1,105) 'slave 1, master 105</td>
</tr>
<tr>
<td>CallTable TenMin</td>
</tr>
<tr>
<td>NextScan</td>
</tr>
<tr>
<td>EndProg</td>
</tr>
</tbody>
</table>

### Unsolicited Responses

Unsolicited responses are similar in concept to the functionality of the CRBasic **SendData()** and **SendVariables()** instructions.

**DNPUpdate()** can enable an unsolicited response transmission. This capability was implemented with datalogger operating system v.28. It enables the datalogger to transmit events without first receiving a request. This mode is useful if the master requires notification soon after a change occurs rather
than waiting for the master to poll the datalogger. Optional `DNPUpdate()` parameters include an unsolicited response timeout, number of retries, and a master connection handle.

If `UnsolicitedResponseConfirmationTimeout` and `UnsolicitedResponseRetries` are not present in `DNPUpdate()`, or if `UnsolicitedResponseConfirmationTimeout = 0`, then unsolicited responses are disabled.

If the `UnsolicitedResponseRetries = 0` then unsolicited responses, with data, will retry indefinitely or until receipt of the data is confirmed by the master.

**Examples**

<table>
<thead>
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<th>CRBasic Example 13. DNPUpdate() Code Snip: Sending Unsolicited Response from Datalogger 1 with Infinite Retries</th>
</tr>
</thead>
<tbody>
<tr>
<td>'Send unsolicited response to master address 3 from datalogger 1; 'wait up to 5 seconds for confirmation that response received; retry indefinitely or 'until response is confirmed by master</td>
</tr>
<tr>
<td>DNPUpdate(1,3,5,0)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>CRBasic Example 14. DNP() Code Snip: Sending Unsolicited Response from Datalogger 1 with Three Retries</th>
</tr>
</thead>
<tbody>
<tr>
<td>'Send unsolicited response to master address 3 from datalogger 1; 'wait up to 5 seconds for confirmation that response received; retry 3 times or 'until response is confirmed by master</td>
</tr>
<tr>
<td>DNPUpdate(1,3,5,3)</td>
</tr>
</tbody>
</table>

**Master Connection Handle**

`DNPUpdate()` optionally specifies a master connection handle when the datalogger needs to initiate a TCP connection to the master rather than wait for the master to initiate a connection to the datalogger. `MasterConnectionHandle` is a variable declared `As LONG`.

**Example**

<table>
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<tr>
<th>CRBasic Example 15. Complete Program: Sending Unsolicited Response from Datalogger 1 via TCP/IP</th>
</tr>
</thead>
<tbody>
<tr>
<td>'Send unsolicited response to master address 10 from datalogger 1 via a TCP connection initiated by the slave.</td>
</tr>
<tr>
<td>Public IP_Socket As Long</td>
</tr>
<tr>
<td>Public Binput(2) As Boolean</td>
</tr>
<tr>
<td>Public counter As Long</td>
</tr>
<tr>
<td>Const = IPAddress =&quot;192.168.xx.xx&quot;</td>
</tr>
<tr>
<td>BeginProg</td>
</tr>
<tr>
<td>DNP(20000,115200,1000)</td>
</tr>
<tr>
<td>DNPVariable (Binput(),2,1,2,0,0,0,0)</td>
</tr>
<tr>
<td>DNPVariable (Binput(),2,2,1,1,0,0,2)</td>
</tr>
<tr>
<td>Scan(1,Sec,1,0)</td>
</tr>
<tr>
<td>IP_Socket = TCPOpen(IPAddress,20000,0)</td>
</tr>
<tr>
<td>counter = counter +1</td>
</tr>
<tr>
<td>DNPUpdate(1,10,5,0,IP_Socket)</td>
</tr>
<tr>
<td>NextScan</td>
</tr>
<tr>
<td>EndProg</td>
</tr>
</tbody>
</table>
DNP3 with Campbell Scientific Dataloggers

Complete Program Example

CRBasic Example 16. Complete Program for a Sample Application

'Solar Energy Monitoring Station
'Written for CR1000 and CR800 series dataloggers. Adaptable to CR6 and CR3000 with
'minor changes.

'Variables for Measurements
Public BattV
Public PTemp
Public Air_Temp
Public Irradiance_GH
Public Irradiance_POA
Public WindSpeed
Public WindDir
Public Rain
Public Daily_Rain

'Declare Units for measurements
Units BattV = Volts
Units PTemp = Deg C
Units Air_Temp = Deg C
Units Irradiance_GH = W/m^2
Units Irradiance_POA = W/m^2
Units WindSpeed = meters/second
Units WindDir = degrees
Units Rain = mm

'Constants used to set up com2 in ppp mode
Const GH_Sensitivity = 14.2
Const POA_Sensitivity = 12.29
,

'Variable declarations for DNP3
Dim i
Dim Heartbeat
Dim Analog_Inputs(9) As Long
Dim Analog_Inputs_Flag(9) As Long

'Data table to record 1 minute or 10 minute averaged measurements
DataTable(TenMin,True,-1)
DataInterval(0,10,Min,10)
Minimum(1,BattV,FP2,False,False)
Average(1,PTemp,FP2,False)
Average(1,Irradiance_GH,FP2,False)
StdDev(1,Irradiance_GH,FP2,False)
Average(1,Irradiance_POA,FP2,False)
StdDev(1,Irradiance_POA,FP2,False)
Average(1,Air_Temp,FP2,False)
StdDev(1,Air_Temp,FP2,False)
WindVector(1,WindSpeed,WindDir,FP2,False,0,0,4)
FieldNames("WindDir_D1_WVT,WindDir_SD1_WVT")
Totalize(1,Rain,FP2,0)
EndTable

'Main Program
BeginProg

10
SET UP THE SOLAR800 AS A DNP3 REMOTE DEVICE

FOR I = 1 TO 9
    Analog_Inputs_Flag(i) = 1 'INITIALIZE DNP3 FLAGS TO ONLINE
NEXT I

DNP(20000,115200,1000) 'SET UP COMMS PORT
DNPVariable(Analog_Inputs(),9,30,2,0,Analog_Inputs_Flag(),0,0) 'STATIC DATA

'EVENT DATA, 120 POINT BUFFER, ANY CHANGE, ALL EVENTS ARE CLASS 1
DNPVariable(Analog_Inputs(),9,32,2,1,Analog_Inputs_Flag(),0,120)

Scan(1,Sec,0,0)
PanelTemp(PTemp,250)
Battery(BattV)

'CREATE A HEARTBEAT
IF Heartbeat = 100 THEN 'INCREMENTS EVERY SECOND UP TO 100, THEN STARTS OVER AT 0
    Heartbeat = 1
ELSE
    Heartbeat = Heartbeat + 1
ENDIF

'GLOBAL HORIZONTAL IRRADIANCE MEASUREMENT
VoltDiff(Irradiance_GH,1,mV25,1,True,0,_60Hz,1000/GH_Sensitivity,0)

'POA IRRADIANCE MEASUREMENT
VoltDiff(Irradiance_POA,1,mV25,2,True,0,_60Hz,1000/POA_Sensitivity,0)

'WIND SPEED MEASUREMENT
PulseCount(WindSpeed,1,1,1,0.75,0.2)
IF WindSpeed<0.21 THEN WindSpeed=0

'WIND DIRECTION MEASUREMENT
BrHalf(WindDir,1,mV2500,5,1,2500,True,0,_60Hz,352,0)
IF WindDir>=360 THEN WindDir=0

'RAIN GAGE MEASUREMENT
PulseCount(Rain,1,2,2,0,0.254,0)

'109 TEMPERATURE PROBE MEASUREMENT DEGREES C
Therm109(Air_Temp,1,6,1,0,_60Hz,1,0)

'UPDATE DNP3 ANALOG INPUTS
Analog_Inputs(1) = Heartbeat
Analog_Inputs(2) = BattV *10
Analog_Inputs(3) = PTemp *10
Analog_Inputs(4) = Irradiance_GH * 10
Analog_Inputs(5) = Irradiance_POA * 10
Analog_Inputs(6) = WindSpeed * 10
Analog_Inputs(7) = WindDir * 10
Analog_Inputs(8) = Air_Temp * 10
Analog_Inputs(9) = Rain * 10

DNPUpdate(1,10) 'SLAVE, MASTER
CallTable TenMin
NextScan
NextProg
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