ModScan

A SCADA MODBUS Network Scanner

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Agenda

- Brief introduction to SCADA Systems
- The MODBUS Protocol
- MODBUS TCP
- ModScan Demonstration
- ModScan Project Information
- Q&A

Disclaimer

- The material in this presentation is to be used for authorized security scanning/ auditing
- If you do something stupid with the information I present here, don't blame me

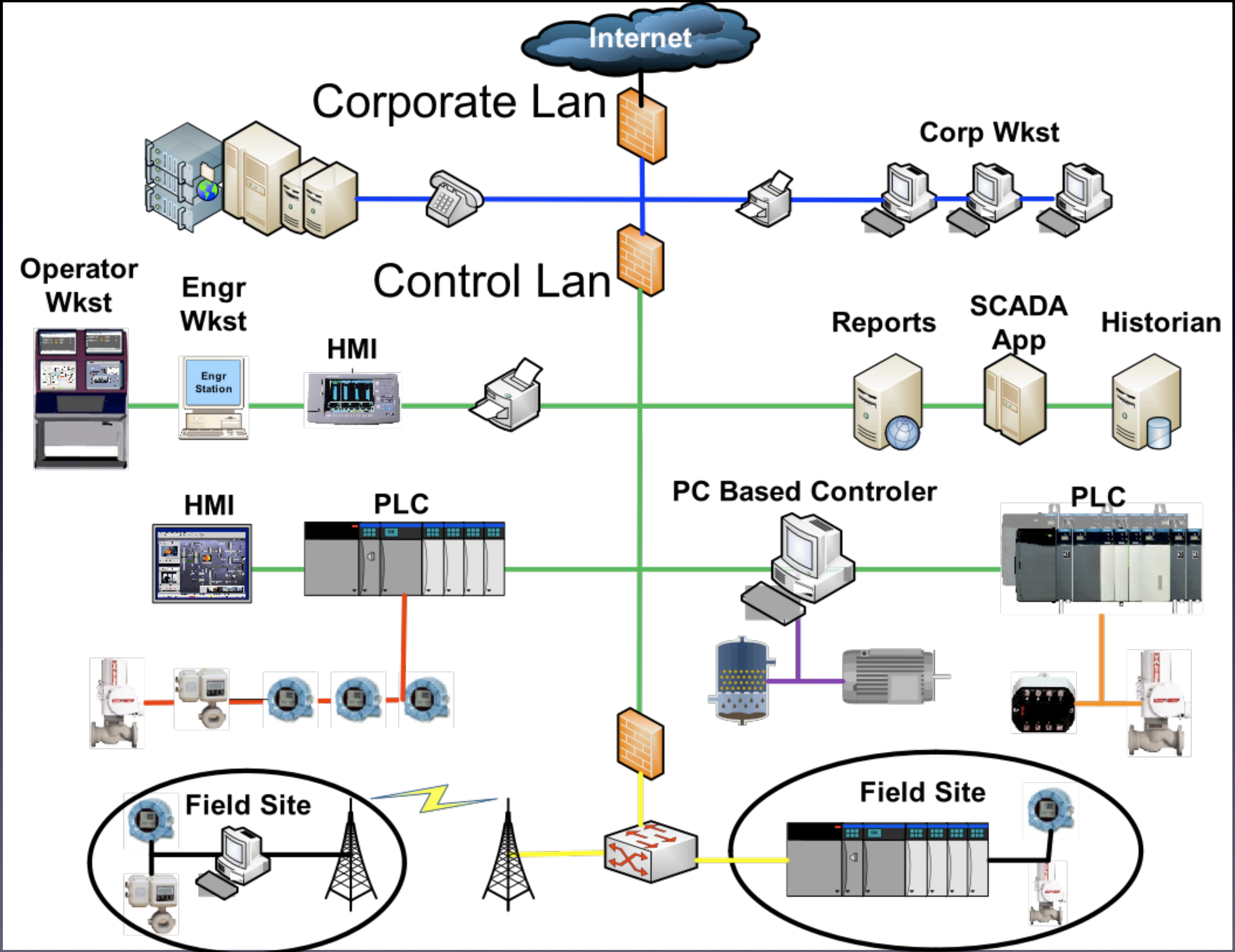
What is SCADA?

- Supervisory Control And Data Acquisition is a system that centrally gathers data in real time from local and remote locations in order to control equipment and conditions.
- Commonly also referred to as Industrial Control Systems (ICS), which is not accurate but close

Where is SCADA?

- Power Generation/Transmission
- Water Treatment/Distribution
- Pipelines
- Traffic Control Systems
- Manufacturing Facilities
- National Infrastructure
- Communications

SCADA Architecture



What is ModScan?

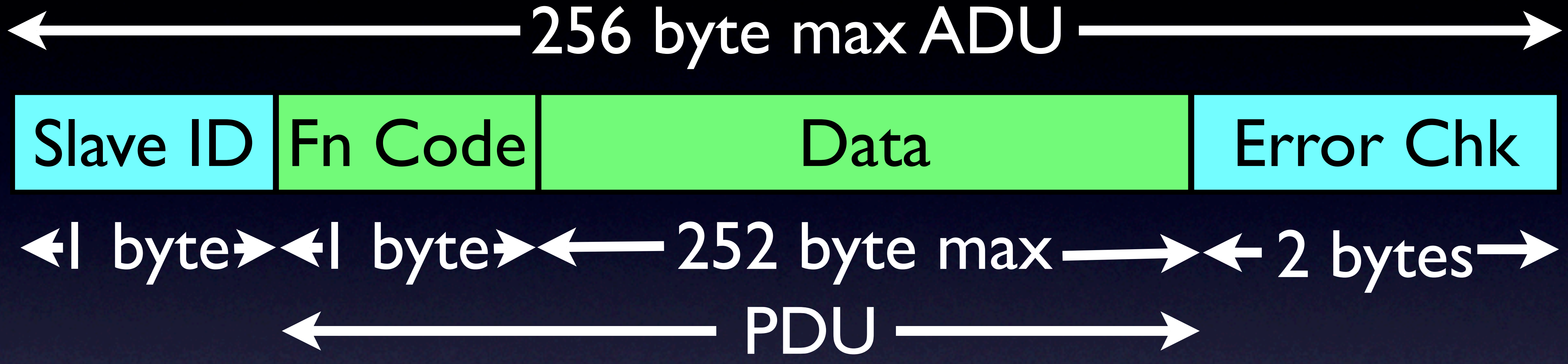
- ModScan is a tool to detect open MODBUS/TCP ports and identify device Slave IDs associated with IP addresses

- ModScan is designed for an administrator or security auditor to be able to accurately reconnoiter a MODBUS/TCP network

The MODBUS Protocol

- About the Protocol
    - Developed in 1979 by Modicon
    - Free and Open Source
    - The most common protocol found in SCADA and ICS networks
    - Default port 503
- Flavors
    - Modbus RTU - Compact Binary
    - Modbus ASCII - Human readable

MODBUS Packet Construction



256 byte max ADU

Slave ID | Fn Code | Data | Error Chk

1 byte | 1 byte | 252 byte max | 2 bytes

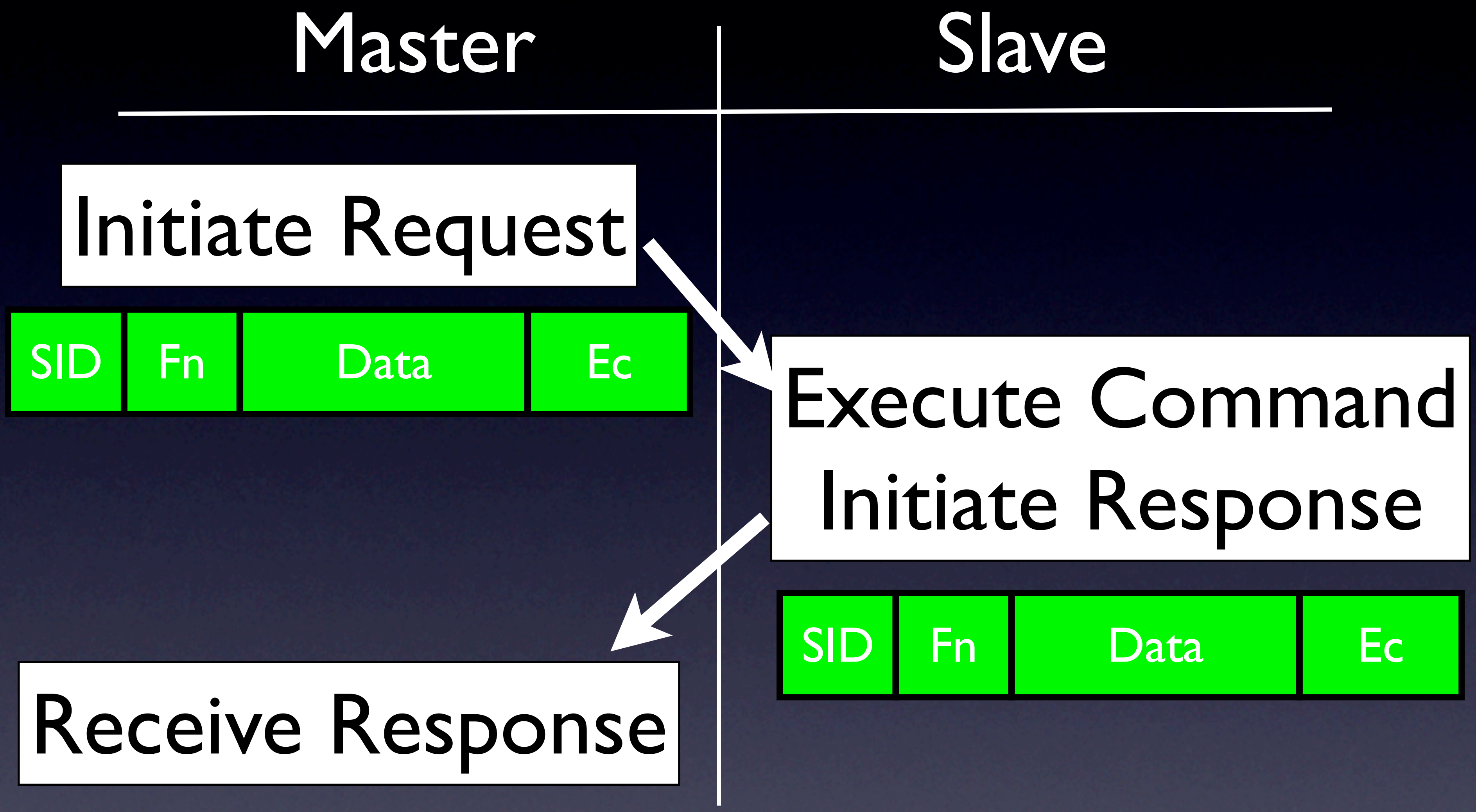
PDU

ADU: Application Data Unit

PDU: Protocol Data Unit

- Valid Function codes are 1-127
- 256 byte maximum packet size
- Big-Endian encoding
- Error Check is CRC/LRC

Typical Communication



Master

Slave

Initiate Request

SID	Fn	Data	Ec

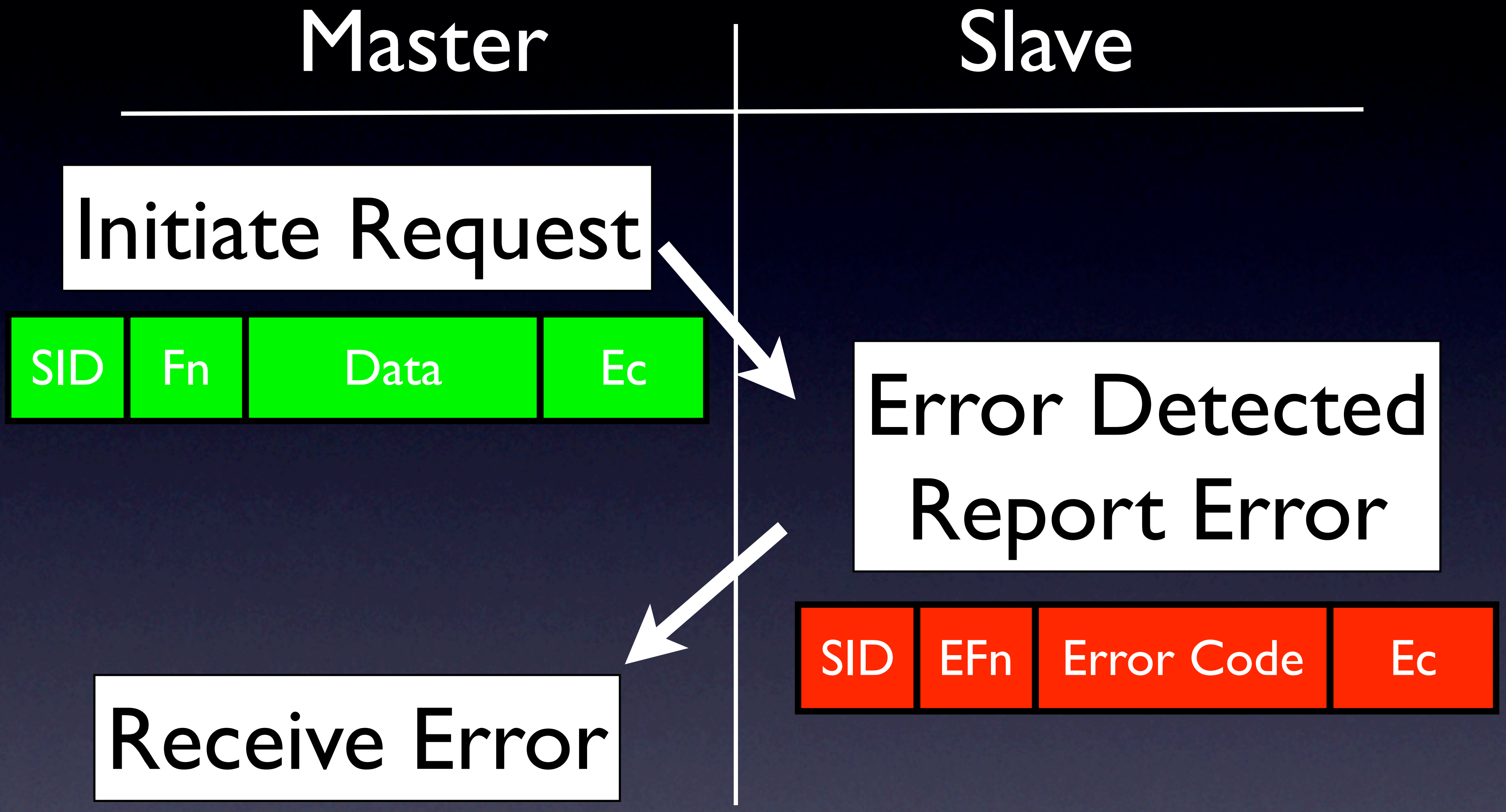
Execute Command
Initiate Response

SID	Fn	Data	Ec

Receive Response

- Modbus is a Master/Slave Serial Protocol
- Only Masters can initiate conversation

Error Communication



Master

Slave

Initiate Request

SID	Fn	Data	Ec

Error Detected
Report Error

SID	EFn	Error Code	Ec

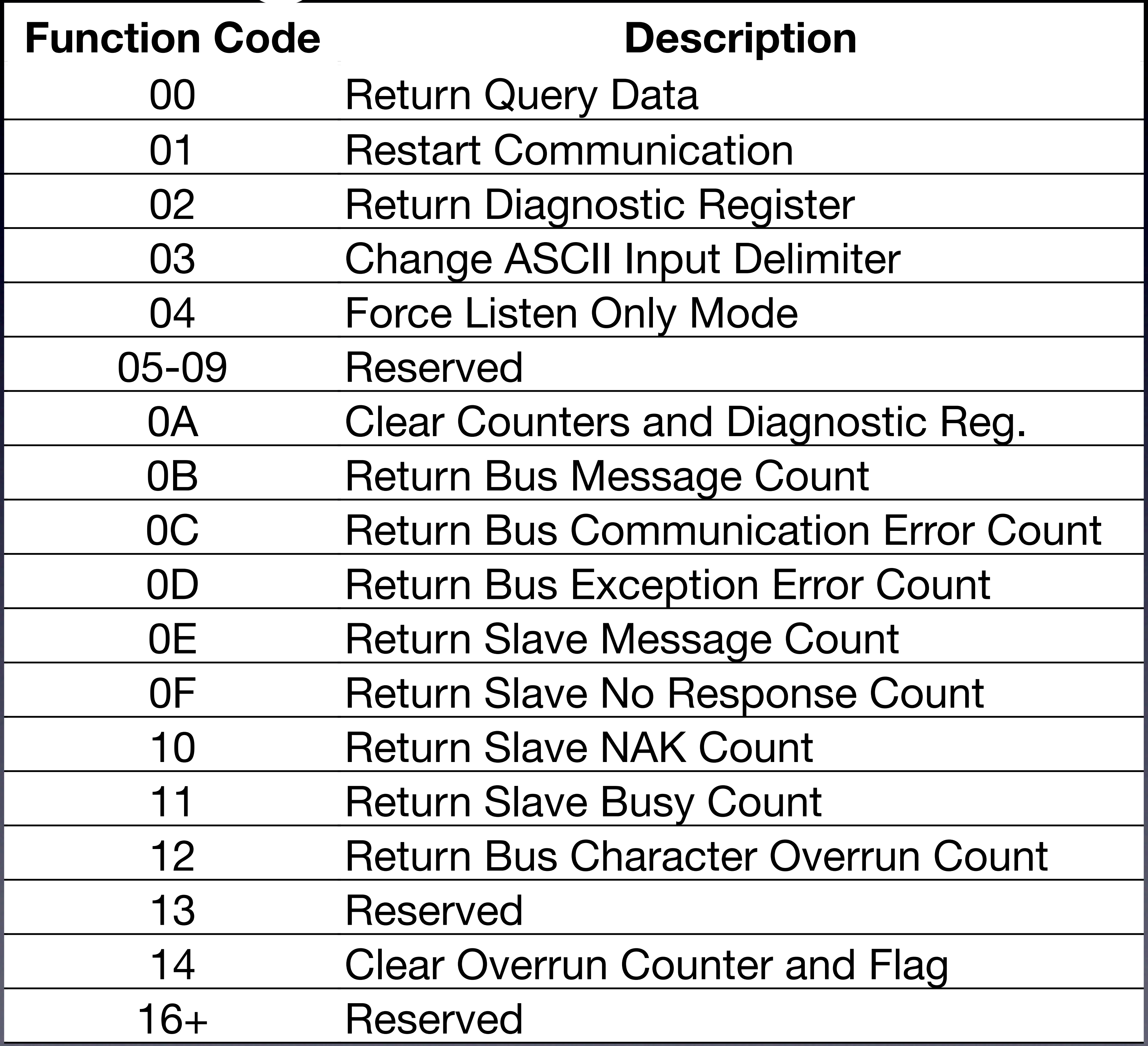
Receive Error

- Error Function = 0x80 + Function Code
- Error Codes defined in specification

Function Codes

Function Code	Description
01	Read Coils
02	Read Discretes
03	Read Holding Registers
04	Read Input Registers
05	Write Coil
06	Write Register
07	Read Exception Status
08	Diagnostics
0B	Get Comm Event Counter
0C	Get Comm Event Log
0F	Write Multiple Coils
10	Write Multiple Registers
11	Report Slave ID
14	Read File Record
15	Write File Record
16	Mask Write Register
17	Read/Write Multiple Registers
18	Read FIFO Que

Diagnostic Codes



Function Code	Description
00	Return Query Data
01	Restart Communication
02	Return Diagnostic Register
03	Change ASCII Input Delimiter
04	Force Listen Only Mode
05-09	Reserved
0A	Clear Counters and Diagnostic Reg.
0B	Return Bus Message Count
0C	Return Bus Communication Error Count
0D	Return Bus Exception Error Count
0E	Return Slave Message Count
0F	Return Slave No Response Count
10	Return Slave NAK Count
11	Return Slave Busy Count
12	Return Bus Character Overrun Count
13	Reserved
14	Clear Overrun Counter and Flag
16+	Reserved

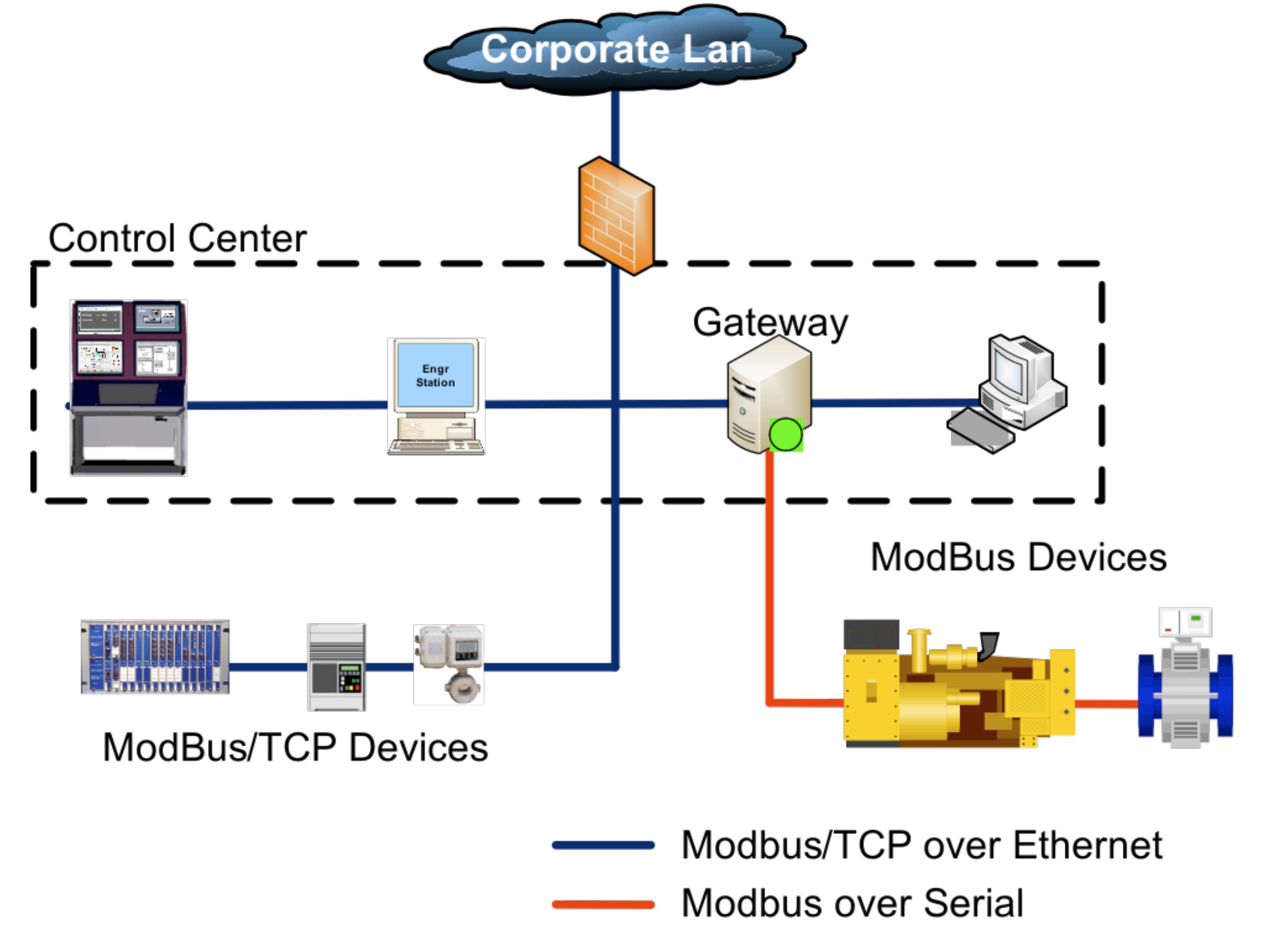
Modbus Notes

- Addressing
  - Valid Slave IDs 1-247
  - Slave ID must be unique per bus
  - Masters do not have to have an address
  - Slaves will error when improperly addressed
- Communication
  - One request on the line at a time
  - Masters must wait for responses

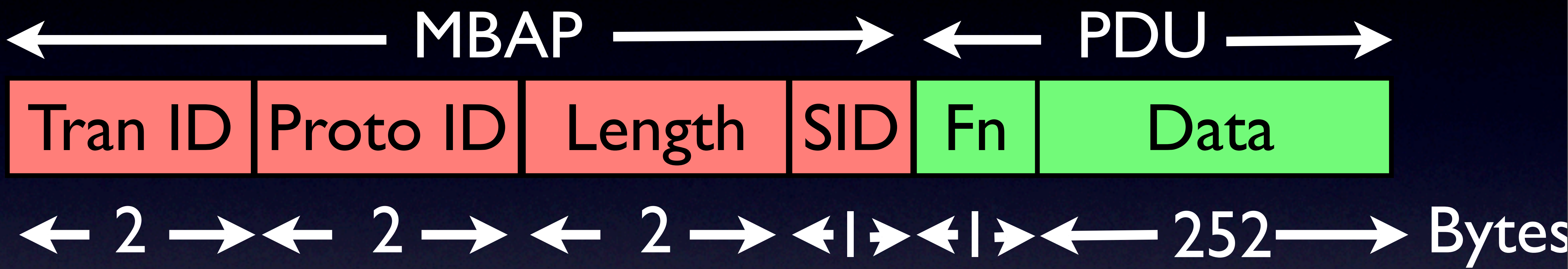
ModBus/TCP

- ModBus protocol wrapped in TCP Goodness
- Checksum dropped
- Introduces Gateway device to ModBus
- Port 502 is reserved for Modbus/TCP
- No additional inherent security measures

ModBus/TCP Architecture



ModBus/TCP Packet

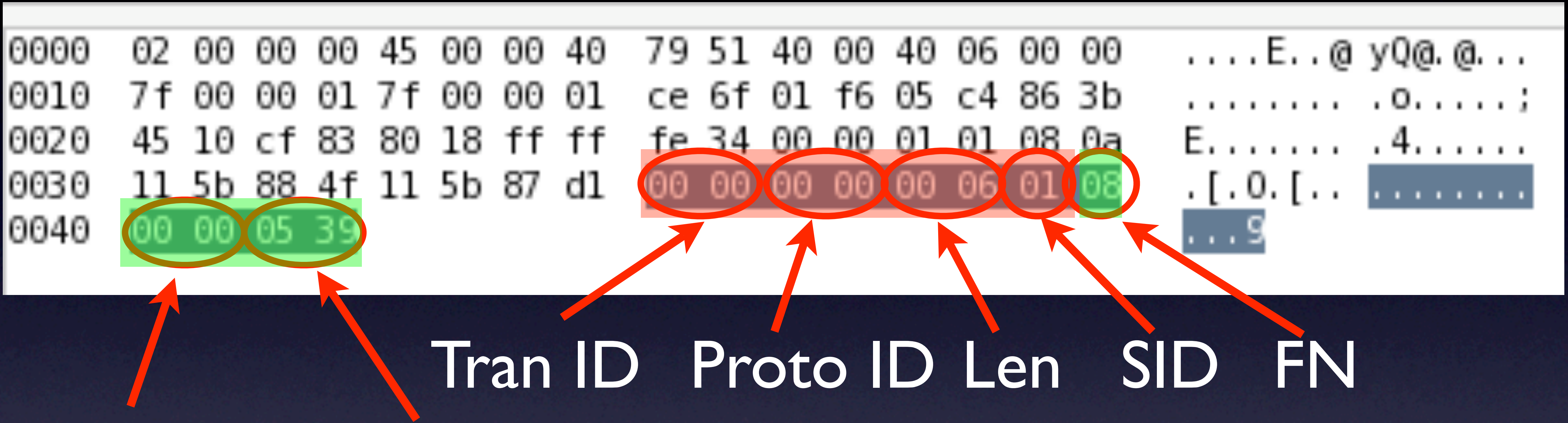


MBAP				PDU	
Tran ID	Proto ID	Length	SID	Fn	Data
2	2	2	1	1	252

Bytes

- MBAP: MODBUS Application Protocol Header
- PDU remains the same from the MODBUS spec
- Protocol ID is always 0x0000
- Big-Endian encoding

Example Request



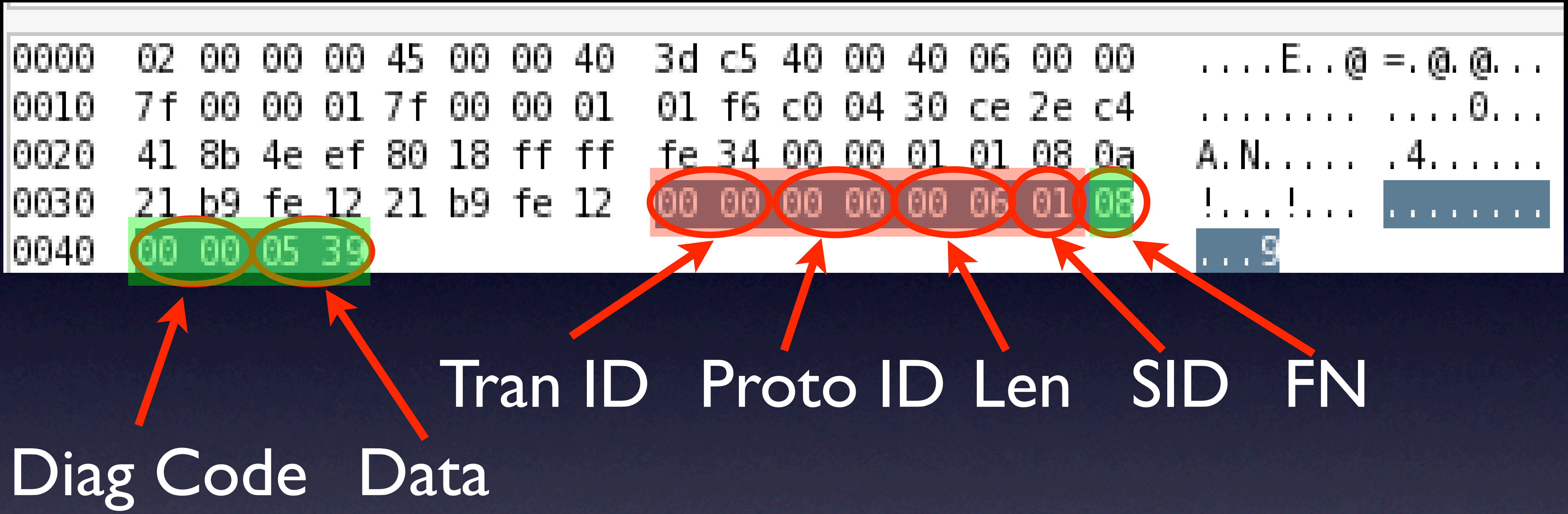
```
0000  02 00 00 00 45 00 00 40  79 51 40 00 40 06 00 00   ....E..@ yQ@.@...
0010  7f 00 00 01 7f 00 00 01  ce 6f 01 f6 05 c4 86 3b   ........ .o.....;
0020  45 10 cf 83 80 18 ff ff  fe 34 00 00 01 01 08 0a   E....... .4......
0030  11 5b 88 4f 11 5b 87 d1  00 00 00 00 00 06 01 08   .[.O.[.. ........
0040  00 00 05 39                                        ...9
```

Tran ID Proto ID Len SID FN

Diag Code Data

- Request sent by Master
- Request is to Slave 01 Fn 8 Diagnostics
- Diagnostic code 00 for "Return Query Data"

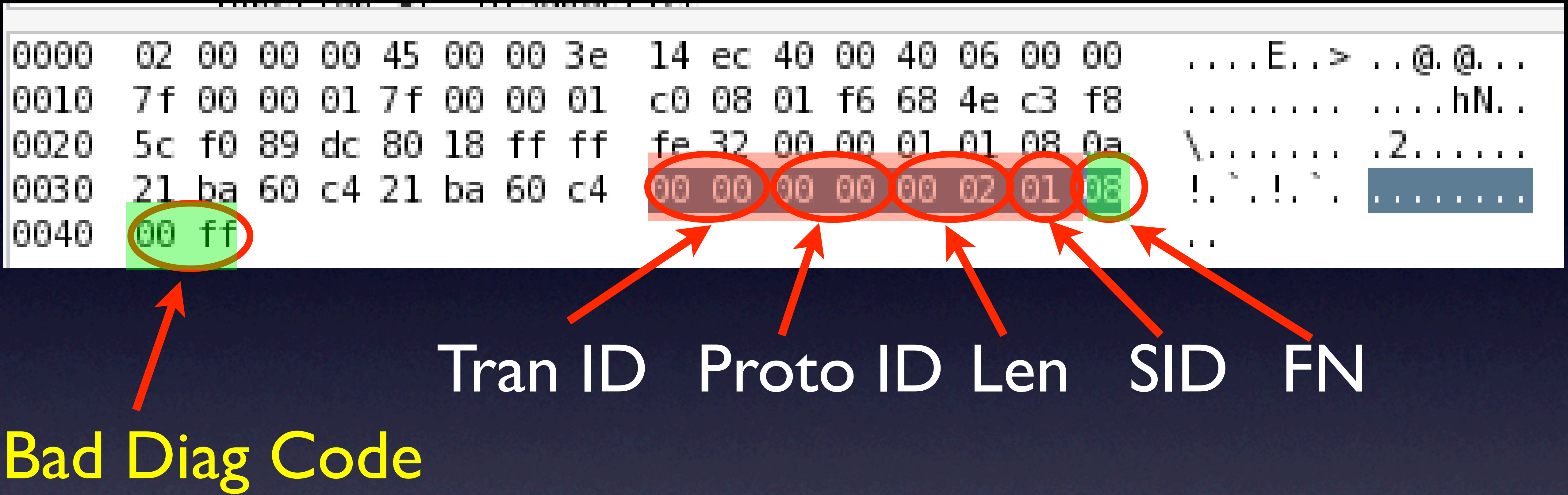
Example Response



```
0000   02 00 00 00 45 00 00 40  3d c5 40 00 40 06 00 00   ....E..@ =.@.@...
0010   7f 00 00 01 7f 00 00 01  01 f6 c0 04 30 ce 2e c4   ........ ....0...
0020   41 8b 4e ef 80 18 ff ff  fe 34 00 00 01 01 08 0a   A.N..... .4......
0030   21 b9 fe 12 21 b9 fe 12  00 00 00 00 00 06 01 08   !...!... ........
0040   00 00 05 39                                        ...9
```

- Response sent by slave
- Request is to Slave 01 Fn 8 Diagnostics
- Diagnostic code 00 for "Return Query Data"
- Identical to Request

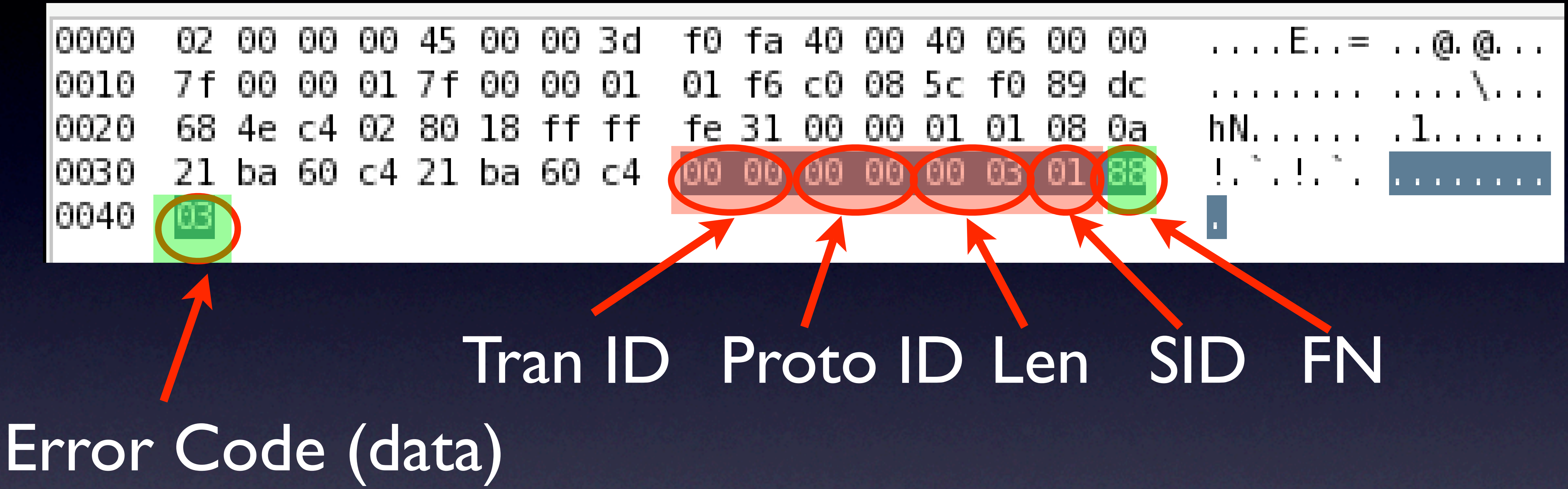
Error Request



```
0000  02 00 00 00 45 00 00 3e  14 ec 40 00 40 06 00 00   ....E..> ..@.@...
0010  7f 00 00 01 7f 00 00 01  c0 08 01 f6 68 4e c3 f8   ........ ....hN..
0020  5c f0 89 dc 80 18 ff ff  fe 32 00 00 01 01 08 0a   \....... .2......
0030  21 ba 60 c4 21 ba 60 c4  00 00 00 00 00 02 01 08   !.`.!.`. ........
0040  00 ff                                              ..
```

- Request is to Slave 01 Fn 8 Diagnostics
- Diagnostic code FF sent

Error Response



```
0000  02 00 00 00 45 00 00 3d  f0 fa 40 00 40 06 00 00   ....E..= ..@.@...
0010  7f 00 00 01 7f 00 00 01  01 f6 c0 08 5c f0 89 dc   ........ ....\...
0020  68 4e c4 02 80 18 ff ff  fe 31 00 00 01 01 08 0a   hN...... .1......
0030  21 ba 60 c4 21 ba 60 c4  00 00 00 00 00 03 01 88   !.`.!.`. ........
0040  03                                                 .
```

Tran ID Proto ID Len SID FN

Error Code (data)

- Function code is 0x88 or 0x08 + 0x80
- Specific Error codes are returned in data field
- Error 0x03 is Illegal data value

Errors are the Key

- When an improper SID is sent
  - The slave will not respond
  - The slave will respond with FN+0x80
- When a proper SID is sent
  - The slave will respond with a valid response
- This forms the basis for mapping

ModScan

- Modscan Scans the IP range provided for open 503 ports
- When an open port is found it finds the SID via brute force
- By default it stops after first discovered SID
- Output in “IP:Port\tSID” format

Options

- -p PORT (502)
- -t TIMEOUT socket timeout (100 mills)
- -a --aggressive Aggressive Mode
- -f FUNCTION MODBUS Function Code (17)
- --data Data for use with -f
- -v, -d Verbose, Debug

ModScan Demonstration

- Scanning our sample network
- A look at a pcap
- Demo of additional Options

ModScan Project

- http://modscan.googlecode.com
- Uses
  - Security Network Enumeration
  - IDS/Network Monitoring Test
  - Asset Management
  - Bulk Commands

Known Issues

- Really, Really Noisy
- Brute forcing all ports is inefficient
- Does not interpret Error Codes
  - Can generate false negatives
- Does not calculate Length
- TCP Checksum not properly calculated

Planned Enhancements

- Interpret Error Codes
- Implement with SCAPY
- Additional Protocol Support
- Device Fingerprinting

- Anything cool someone suggests....

Questions?

References

- http://en.wikipedia.org/wiki/SCADA
- http://www.modbus.org/specs.php
- http://www.wingpath.co.uk

Contact Information

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