Industrial Automation Bit Error Rate

David D. Brandt

Rockwell Automation

Purpose

- The purpose of this presentation is to show a calculation of the required bit error rate for an Ethernet PHY utilized in industrial automation
  - Random bit errors are assumed
  - Bit error rate is after correction
    - Considered detectable
    - The frame is discarded
  - Burst errors due to interference are not considered herein

Result of lost connections

- Automation must maintain knowledge of the state of the system
  - Through periodic updates on a “connection”

- If any connection is lost, a fault may occur:
  - Human intervention may be required
    - Unjam equipment
    - Rerun safety procedures
  - Product may be lost

Example Scenario

- A large plant has 100 k networked devices
- Each device has 2 connections, one to receive output values and one to report input values
- Each connection sends an update every 10 ms
- Each message averages 125 B (1000 bits)
- Control protocols use oversampling techniques to tolerate message loss
  - With a timeout of 3x the update period, each connection can tolerate up to 2 lost messages in a row

➢ It is acceptable to lose one connection per year in a plant due to random packet loss

Definitions

Parameter	Description	Units
D	Ethernet devices in a facility	
C	Average connections per device	
R	Update Rate	packets/s
L	Packet Length	bits
N	Maximum packets lost in a row	
T	Connection Loss Interval	s
CER	Connection Error Rate	
PER	Packet Error Rate	
BER	Bit Error Rate	

Connection Error Rate

- Each device has multiple connections (at least one to and from the device)
- If there are D devices in a plant and they average C connections per device, the acceptable connection error rate (CER) over an interval T is:
  - CER = 1/(D*C)

Packet Error Rate

- In an interval T, each connection transmits a number of packets P at a rate R, then P = R*T
- If the probability of a single packet loss is PER, the probability of N lost in a row (a connection loss) is PER^N
- In a long stream of packets, the number of combinations of N lost in a row (for small N) ~= the number of packets in the stream
- The interval T, the connection error rate CER = number of packets in T * probability of N lost in a row
  - CER = P*PER^N
  - PER = (CER/(R*T))^(1/N)

Bit Error Rate

- For a packet length L:
  - BER = PER/L
  - BER = ((CER/(R*T))^(1/N))/L

Use Cases

		C1 Unreasonable	C2 PA, FA1	C3 FA2	C4 FA3	C5 FA Safety
		Extreme size	Extreme size	Extreme size	Moderate size	Small size
Parameter	**Descriptions**	**Extreme performance**	**Low performance**	**High performance**	**Moderate performance**	**Extreme performance**
D	Ethernet devices in a facility	100000	100000	100000	10000	1000
C	Average connections per device	2	2	2	2	2
R	Update Rate (packets/s)	100	10	100	50	100
L	Packet Length (bits)	1000	1000	1000	1000	1000
N	Maximum packets lost in a row	2	3	3	3	2
T	Connection Loss Interval (s)	3.2E+07	3.2E+07	3.2E+07	3.2E+07	3.2E+07
CER	Connection Error Rate	5.0E-06	5.0E-06	5.0E-06	5.0E-05	5.0E-04
PER	Packet Error Rate	4.0E-08	2.5E-05	1.2E-05	3.2E-05	4.0E-07
BER	Bit Error Rate	4.0E-11	2.5E-08	1.2E-08	3.2E-08	4.0E-10

Conclusions

- Adequate Automation Protocol oversampling is necessary
- Use cases suggest BER should at least be better than 10^{-8}
- Automation devices are currently operating in large volume using 10/100M
  - The same 10^{-9} BER objective is appropriate