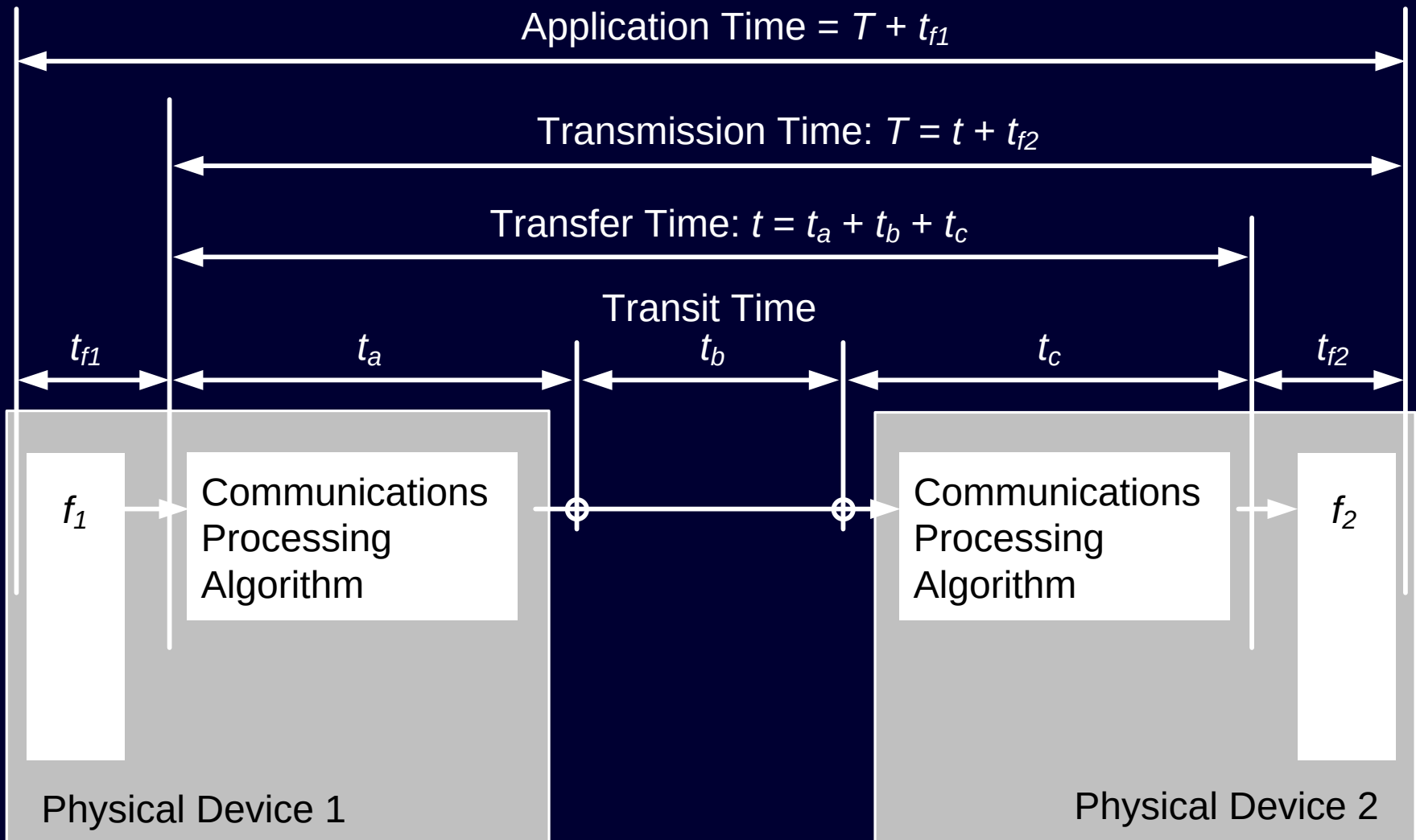


Lessons Learned Through Commissioning and Analyzing Data From Ethernet Network Installations

D. DOLEZILEK and J. DEARIEN
Schweitzer Engineering Laboratories, Inc.

Signal Data Exchange Is Measured as Message Transfer Time



IEC/TR 61850-90-4 Network Engineering Guidelines - Performance and Test

Transfer Time Class	Transfer Time (ms)	Application Example
TT0	>1,000	Files, events, and log contents
TT1	1,000	Events and alarms
TT2	500	Operator commands
TT3	100	Slow automatic interactions
TT4	20	Fast automatic interactions
TT5	10	Releases and status changes
TT6	3	Trips and blockings

Use GOOSE Reports Within IED to Quickly Review Network Settings

Multicast Address 01-0C-CD-01-00-05,
Priority Tag 4, VLAN 2

GOOSE Transmit Status

Reference: PAC_MASTER_01CFG/LLN0\$GO\$Dset14_PAC_M_DO
MultiCastAddr Ptag:Vlan StNum SqNum TTL Code

01-0C-CD-01-00-05 4:2 367 10298 1000
Data Set: PAC_MASTER_01CFG/LLN0\$Dset14_PAC_M_DO

GOOSE Receive Status

Reference: PAC_SLAVE_A_01CFG/LLN0\$GO\$Dset14_PAC_A_DI
MultiCastAddr Ptag:Vlan StNum SqNum TTL Code

01-0C-CD-01-00-01 4:2 60 18106 1198
Data Set: PAC_SLAVE_A_01CFG /LLN0\$Dset14_PAC_A_DI

Reference: PAC_SLAVE_A_01CFG/LLN0\$GO\$Dset15_PAC_A_AI
MultiCastAddr Ptag:Vlan StNum SqNum TTL Code

01-0C-CD-01-00-02 4:2 73185 5 378
Data Set: PAC_SLAVE_A_01CFG /LLN0\$Dset15_PAC_A_AI

Reference: PAC_SLAVE_B_01CFG /LLN0\$GO\$Dset14_PAC_B_AI
MultiCastAddr Ptag:Vlan StNum SqNum TTL Code

01-0C-CD-01-00-03 4:2 102353 3 116
Data Set: PAC_SLAVE_B_01CFG /LLN0\$Dset14_PAC_B_AI

Reference: PAC_SLAVE_C_01CFG /LLN0\$GO\$Dset14_PAC_C_AI
MultiCastAddr Ptag:Vlan StNum SqNum TTL Code

01-0C-CD-01-00-04 4:2 93732 6 0 TTL EXPIRED
Data Set: PAC_SLAVE_C_01CFG /LLN0\$Dset14_PAC_C_AI

Analyze GOOSE Statistics and Diagnostics

Status Number 367,
Sequence Number 10298



GOOSE Transmit Status

Reference: PAC_MASTER_01CFG/LLN0\$GO\$Dset14_PAC_M_DO
MultiCastAddr Ptag/Vlan StNum SqNum TTL Code

01-0C-CD-01-00-01 4:2 367 10298 1000
Data Set: PAC_MASTER_01CFG/LLN0\$Dset14_PAC_M_DO

GOOSE Receive Status

Reference: PAC_SLAVE_A_01CFG/LLN0\$GO\$Dset14_PAC_A_DI
MultiCastAddr Ptag/Vlan StNum SqNum TTL Code

01-0C-CD-01-00-01 4:2 60 18106 1198
Data Set: PAC_SLAVE_A_01CFG/LLN0\$Dset14_PAC_A_DI

Reference: PAC_SLAVE_A_01CFG/LLN0\$GO\$Dset15_PAC_A_AI
MultiCastAddr Ptag/Vlan StNum SqNum TTL Code

01-0C-CD-01-00-02 4:2 73185 5 378
Data Set: PAC_SLAVE_A_01CFG/LLN0\$Dset15_PAC_A_AI

Reference: PAC_SLAVE_B_01CFG/LLN0\$GO\$Dset14_PAC_B_AI
MultiCastAddr Ptag/Vlan StNum SqNum TTL Code

01-0C-CD-01-00-03 4:2 102353 3 116
Data Set: PAC_SLAVE_B_01CFG/LLN0\$Dset14_PAC_B_AI

Reference: PAC_SLAVE_C_01CFG/LLN0\$GO\$Dset14_PAC_C_AI
MultiCastAddr Ptag/Vlan StNum SqNum TTL Code

01-0C-CD-01-00-04 4:2 93732 6 0 TTL EXPIRED
Data Set: PAC_SLAVE_C_01CFG/LLN0\$Dset14_PAC_C_AI

Immediately Detect Problem and Pinpoint the Source

Time To Live 0,
Error Code TTL EXPIRED

Code Abbreviation	Description
OUT OF SEQUENC	Out of sequence error
CONF REV MISMA	Configuration Revision mismatch
NEED COMMISSIO	Needs Commissioning
TEST MODE	Test Mode
MSG CORRUPTED	Message Corrupted
TTL EXPIRED	Time to live expired
HOST DISABLED	Host disabled/not responding

GOOSE Transmit Status

Reference: PAC_MASTER_01CFG/LLN0\$GO\$Dset14_PAC_M_DO
 MultiCastAddr Ptag/Vlan StNum SqNum TTL Code

 01-0C-CD-01-00-05 4:2 367 10298 1000
 Data Set: PAC_MASTER_01CFG/LLN0\$Dset14_PAC_M_DO

GOOSE Receive Status

Reference: PAC_SLAVE_A_01CFG/LLN0\$GO\$Dset14_PAC_A_DI
 MultiCastAddr Ptag/Vlan StNum SqNum TTL Code

 01-0C-CD-01-00-01 4:2 60 18106 1198
 Data Set: PAC_SLAVE_A_01CFG/LLN0\$Dset14_PAC_A_DI

Reference: PAC_SLAVE_A_01CFG/LLN0\$GO\$Dset15_PAC_A_AI
 MultiCastAddr Ptag/Vlan StNum SqNum TTL Code

 01-0C-CD-01-00-02 4:2 73185 5 378
 Data Set: PAC_SLAVE_A_01CFG/LLN0\$Dset15_PAC_A_AI

Reference: PAC_SLAVE_B_01CFG/LLN0\$GO\$Dset14_PAC_B_AI
 MultiCastAddr Ptag/Vlan StNum SqNum TTL Code

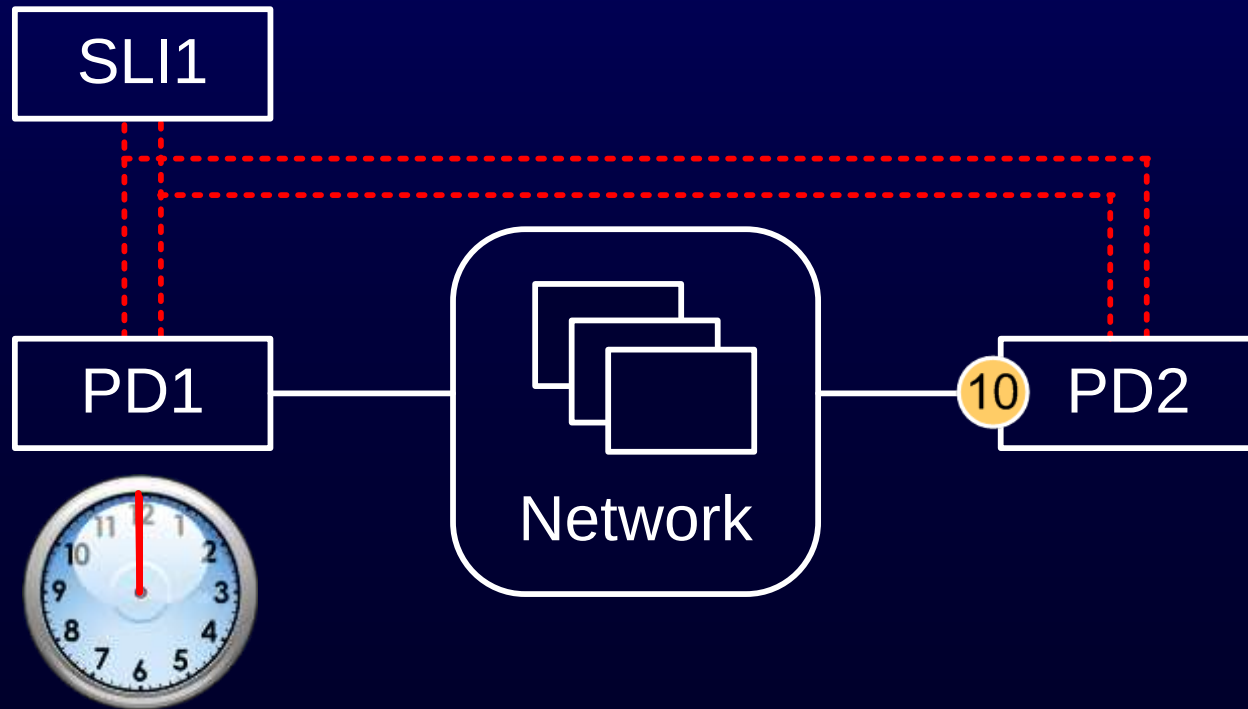
 01-0C-CD-01-00-03 4:2 102353 3 116
 Data Set: PAC_SLAVE_B_01CFG/LLN0\$Dset14_PAC_B_AI

Reference: PAC_SLAVE_C_01CFG/LLN0\$GO\$Dset14_PAC_C_AI
 MultiCastAddr Ptag/Vlan StNum SqNum TTL Code

 01-0C-CD-01-00-04 4:2 93732 6 0
 Data Set: PAC_SLAVE_C_01CFG/LLN0\$Dset14_PAC_C_AI

0 TTL EXPIRED

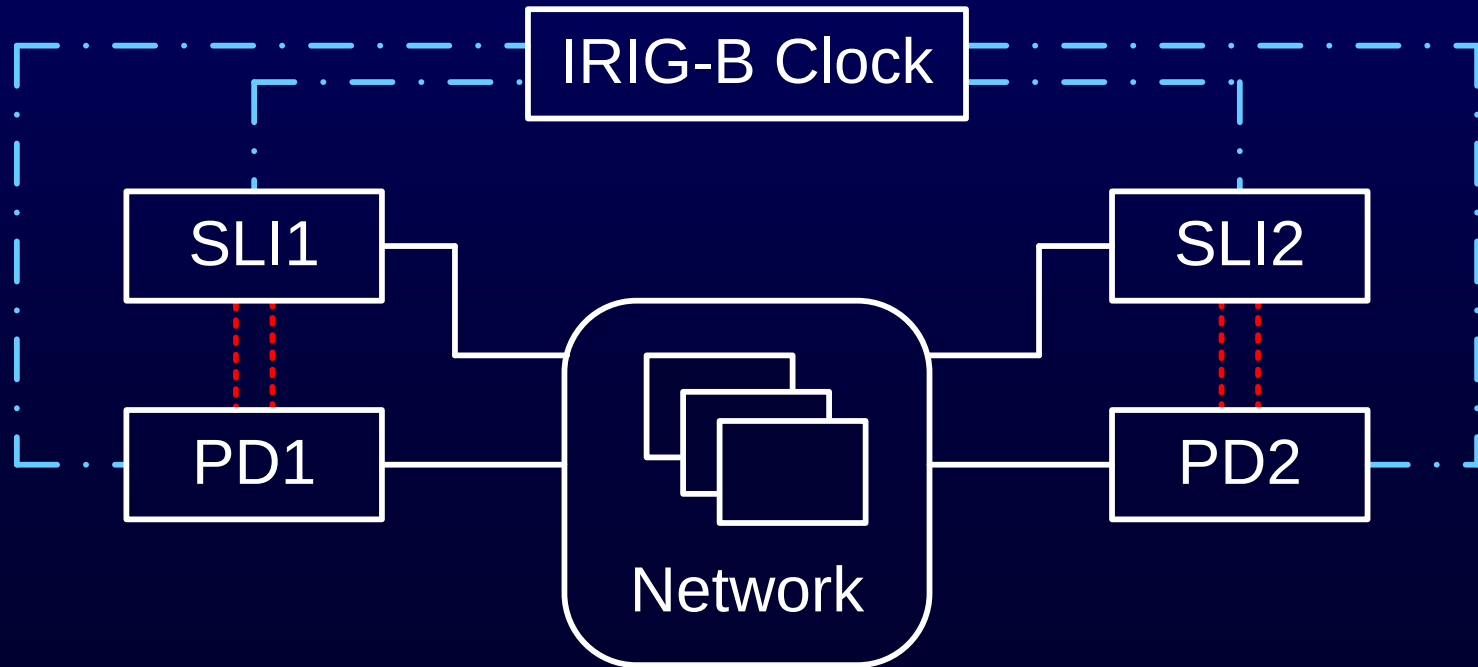
Verify Times for Signal Exchange Triggered by Contact Input



— · — IRIG-B
- - - Wiring
— Ethernet

PD = Physical Device
SLI = Synchronized Logic IED

Application Timing Test Network



	Transmission	Transfer
PD	< 5 ms	< 3 ms
SLI	< 4 ms	< 2 ms

Performance Timing Diagnostics



New Diagnostic Tools Must Also be Within the IEDs

```
=>>goo s 1
```

```
SubsID 1
```

```
Ctrl Ref: SEL_351A_1CFG/LLN0$G0$G00SE0utPri7
```

```
AppID    : 4119
```

```
From      : 07/13/2012 09:15:40.992  To: 07/13/2012 10:26:47.660
```

```
Accumulated downtime duration      : 0000:00:00
```

```
Maximum downtime duration          : 0000:00:00
```

```
Date & time maximum downtime began : 07/13/2012
```

```
Number of messages received out-of-sequence(00S) : 0
```

```
Number of time-to-live(TTL) violations detected  : 1
```

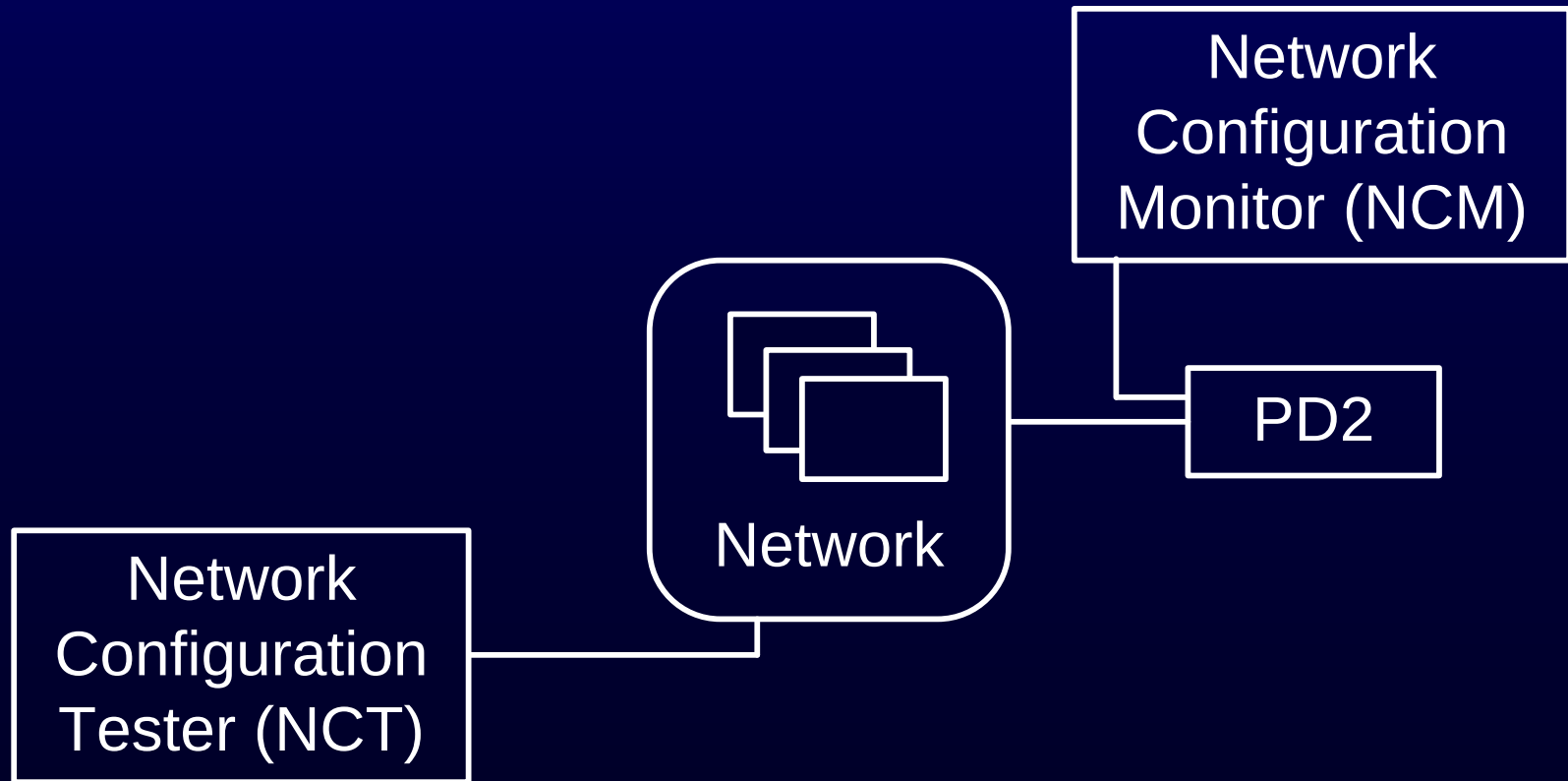
```
Number of messages incorrectly encoded or corrupted: 0
```

```
Number of messages lost due to receive overflow  : 0
```

```
Calculated max. sequential messages lost due to 00S: 0
```

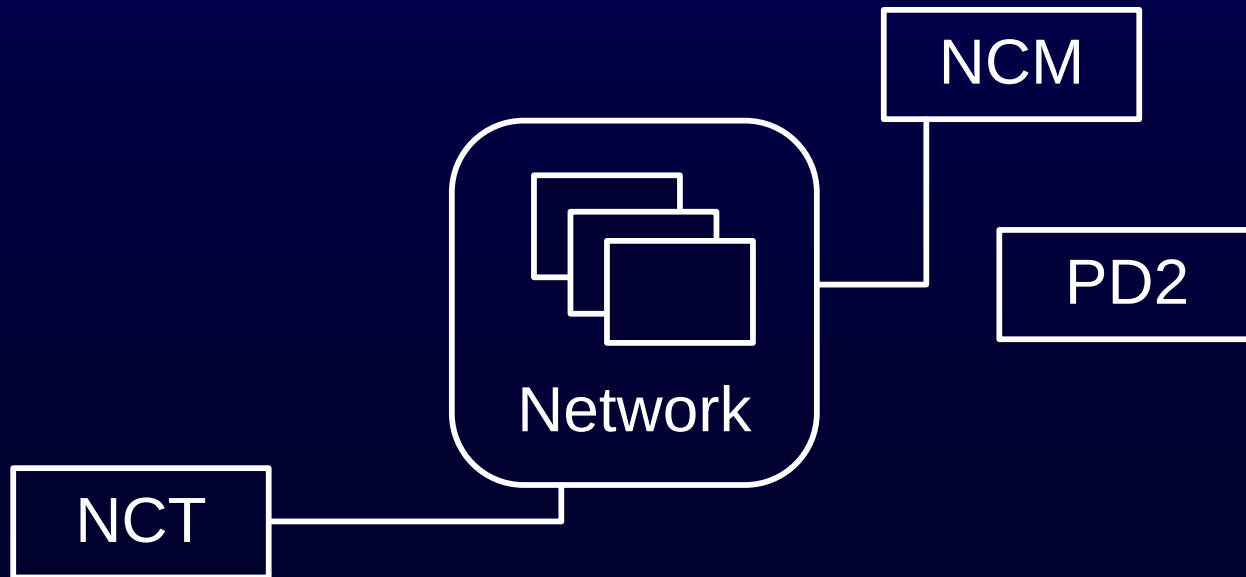
```
Calculated number of messages lost due to 00S    : 0
```

Network Commissioning Requires Configuration Test of IED Ports



IED Ethernet ports set to forward messages

Network Commissioning Requires Configuration Test of IED Ports



Network port test for IEDs that cannot forward Ethernet traffic

Receipt of GOOSE Publications Shows Network Configuration

001	002	003	004	005	006	007	008	009	010	011	012	013	014	015
016	017	018	019	020	021	022	023	024	025	026	027	028	029	030
031	032	033	034	035	036	037	038	039	040	041	042	043	044	045
046	047	048	049	050	051	052	053	054	055	056	057	058	059	060
061	062	063	064	065	066	067	068	069	070	071	072	073	074	075
076	077	078	079	080	081	082	083	084	085	086	087	088	089	090
091	092	093	094	095	096	097	098	099	100	101	102	103	104	105
106	107	108	109	110	111	112	113	114	115	116	117	118	119	120
121	122	123	124	125	126	127	128	129	130	131	132	133	134	135
136	137	138	139	140	141	142	143	144	145	146	147	148	149	150

VLAN

Inactive VLAN

VLAN

Active VLAN



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GOOSE Monitor



GOOSE messages / second

1: SEL_751_1CFG/LLN0\$GOOSE_Test	38
2: SEL_421_1CFG/LLN0\$SEL_421_PBLEds	161
3: SEL_710_1CFG/LLN0\$GOOSE_monitor	51
4: SEL_751A_1CFG/LLN0\$GOOSE_monitor	1

To reset press "LAMP TEST" on RTAC or click:



GOOSE #1

GOOSE channel summary

SEL_751_1CFG/LLN0\$GOOSE_Test

GOOSE OK

Time since reset: T#7m47s797ms

Total offline time: T#0ms

Channel unavailability 0.000000

Normal operation

New data messages received: 3773

Retransmissions received: 11317

Heartbeats received: 71

GOOSE message incidents

Number of offline events: 0

New data lost events: 0

Retransmission lost events: 0

GOOSE #3

GOOSE channel summary

SEL_710_1CFG/LLN0\$GOOSE_monitor

GOOSE OK

Time since reset: T#7m47s832ms

Total offline time: T#0ms

Channel unavailability 0.000000

Normal operation

New data messages received: 595

Retransmissions received: 1190

Heartbeats received: 433

GOOSE message incidents

Number of offline events: 0

New data lost events: 0

Retransmission lost events: 0

GOOSE #2

GOOSE channel summary

SEL_751_1CFG/LLN0\$GOOSE_Test

GOOSE OK

Time since reset: T#7m47s840ms

Total offline time: T#0ms

Channel unavailability 0.000000

Normal operation

New data messages received: 2763

Retransmissions received: 4515

Heartbeats received: 421

GOOSE message incidents

Number of offline events: 0

New data lost events: 0

Retransmission lost events: 0

GOOSE #4

GOOSE channel summary

SEL_751A_1CFG/LLN0\$GOOSE_monitor

GOOSE OK

Time since reset: T#7m47s798ms

Total offline time: T#0ms

Channel unavailability 0.000000

Normal operation

New data messages received: 0

Retransmissions received: 0

Heartbeats received: 467

GOOSE message incidents

Number of offline events: 0

New data lost events: 0

Retransmission lost events: 0



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GOOSE Monitor

GOOSE channel summary

GOOSE OK

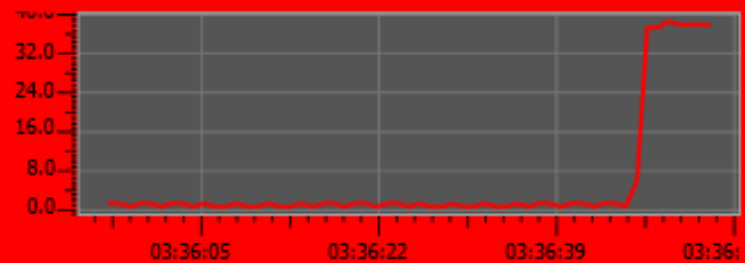
Time since reset: T#1m18s641ms

Total offline time: T#0ms

Channel unavailability 0.000000



GOOSE messages / sec



Normal operation

New data messages

Messages received: 72

Time since last: T#9ms

Time between new data messages:

Average: T#99ms

Maximum: T#106ms

Minimum: T#92ms

Data retransmissions (non-heartbeat)

Retransmissions received: 214

Time since last: T#32ms

Average time between retransmissions:

1: 13 mS	6: 0 mS
2: 22 mS	7: 0 mS
3: 42 mS	8: 0 mS
4: 0 mS	9: 0 mS
5: 0 mS	10: 0 mS

Heartbeat messages

Heartbeats received: 71

Time since last: T#7s554ms

Time between consecutive heartbeats:

Average: T#994ms

Maximum: T#1s3ms

Minimum: T#986ms

GOOSE message incidents

Channel offline

Number of events: 0

Total offline time: T#0ms

Last event

Offline duration: T#0ms

No events since reset

Longest event

Offline duration: T#0ms

No events since reset

New data messages lost

Number of events: 0

Total missed messages: 0

Last event

Missed state changes: 0

No events since reset

Time since last missed data: T#0ms

Event with most lost messages

Missed state changes: 0

No events since reset

Time since last missed data: T#0ms

Data retransmissions lost

Number of events: 0

Total missed messages: 0

Last event

Missed messages: 0

No events since reset

Event with most lost messages

Missed messages: 0

No events since reset

Dataset name:SEL_751_1CFG/LLN0\$GOOSE_Test

To reset press "LAMP TEST" on RTAC or click:
Time of day: DT#2012-08-31-03:50:02



Reset

Tools Within IEDs Monitor and Alarm Missing Messages

=>>goo s 1

SubsID 1

Ctrl Ref: SEL_351A_1CFG/LLN0\$G0\$G00SE0utPri7

AppID : 4119

From : 07/13/2012 09:15:40.992 To: 07/13/2012 10:26:47.660

Accumulated downtime duration : 0000:00:00

Maximum downtime duration : 0000:00:00

Date & time maximum downtime began : 07/13/2012

Number of messages received out-of-sequence(00S) : 0

Number of time-to-live(TTL) violations detected : 1

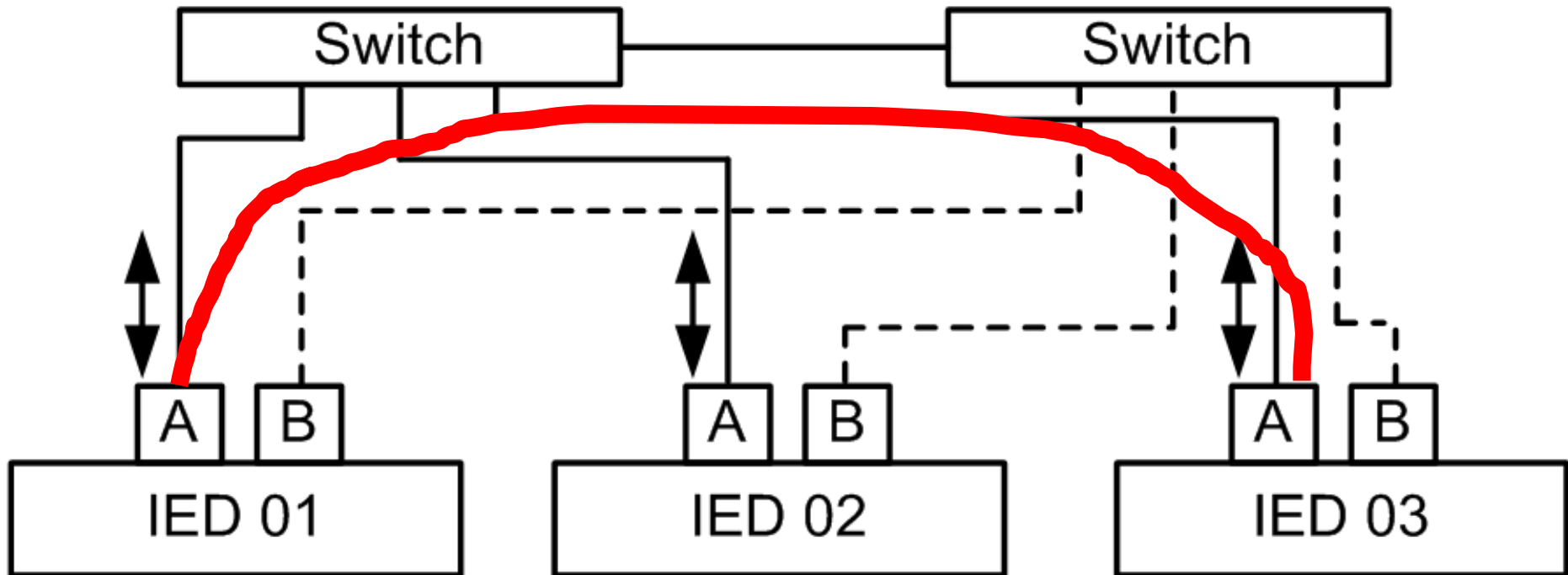
Number of messages incorrectly encoded or corrupted: 0

Number of messages lost due to receive overflow : 0

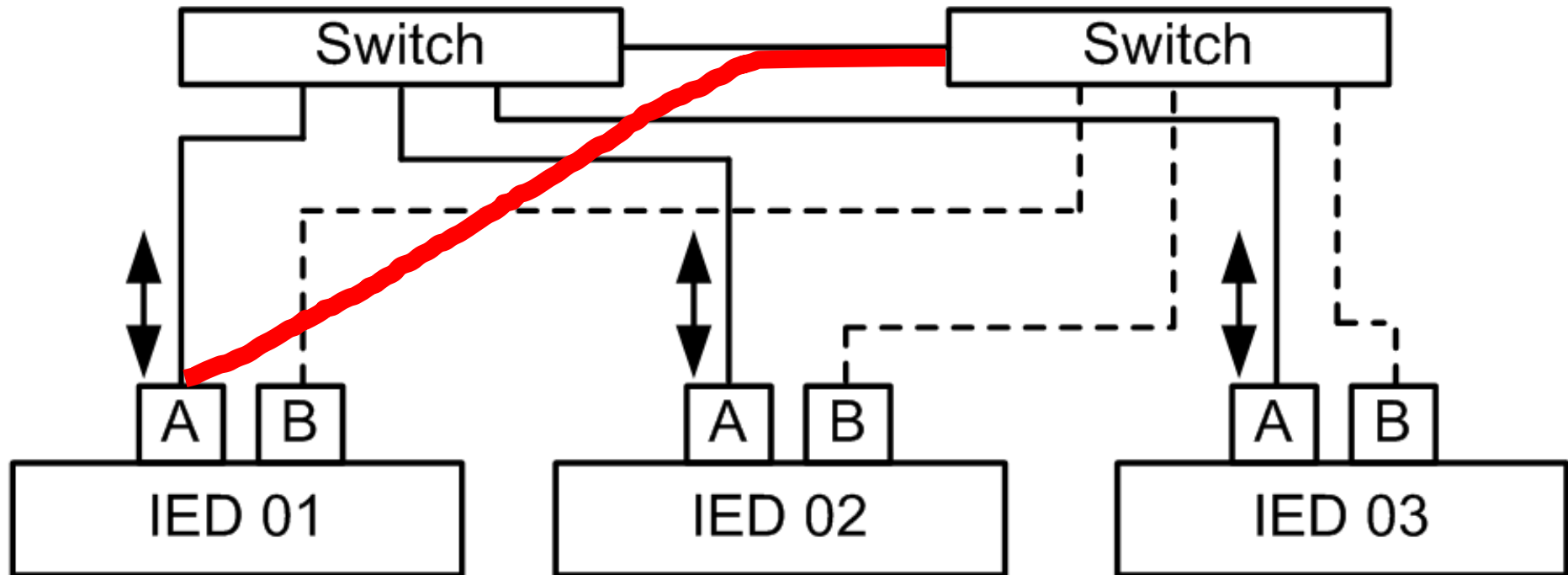
Calculated max. sequential messages lost due to 00S: 0

Calculated number of messages lost due to 00S : 0

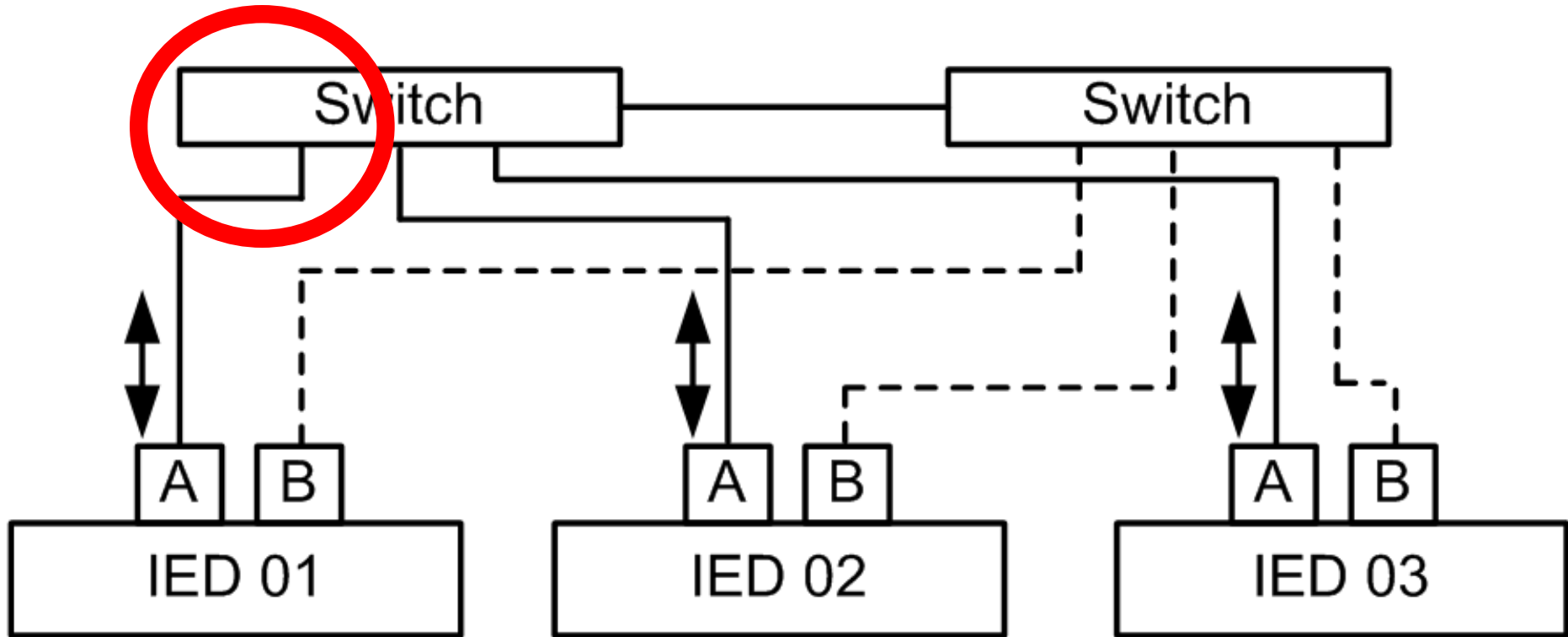
Direct Connect Confirms Publication



Bypass Switch Confirms Subscription



Problem is Switch, Switch Port, or Cable

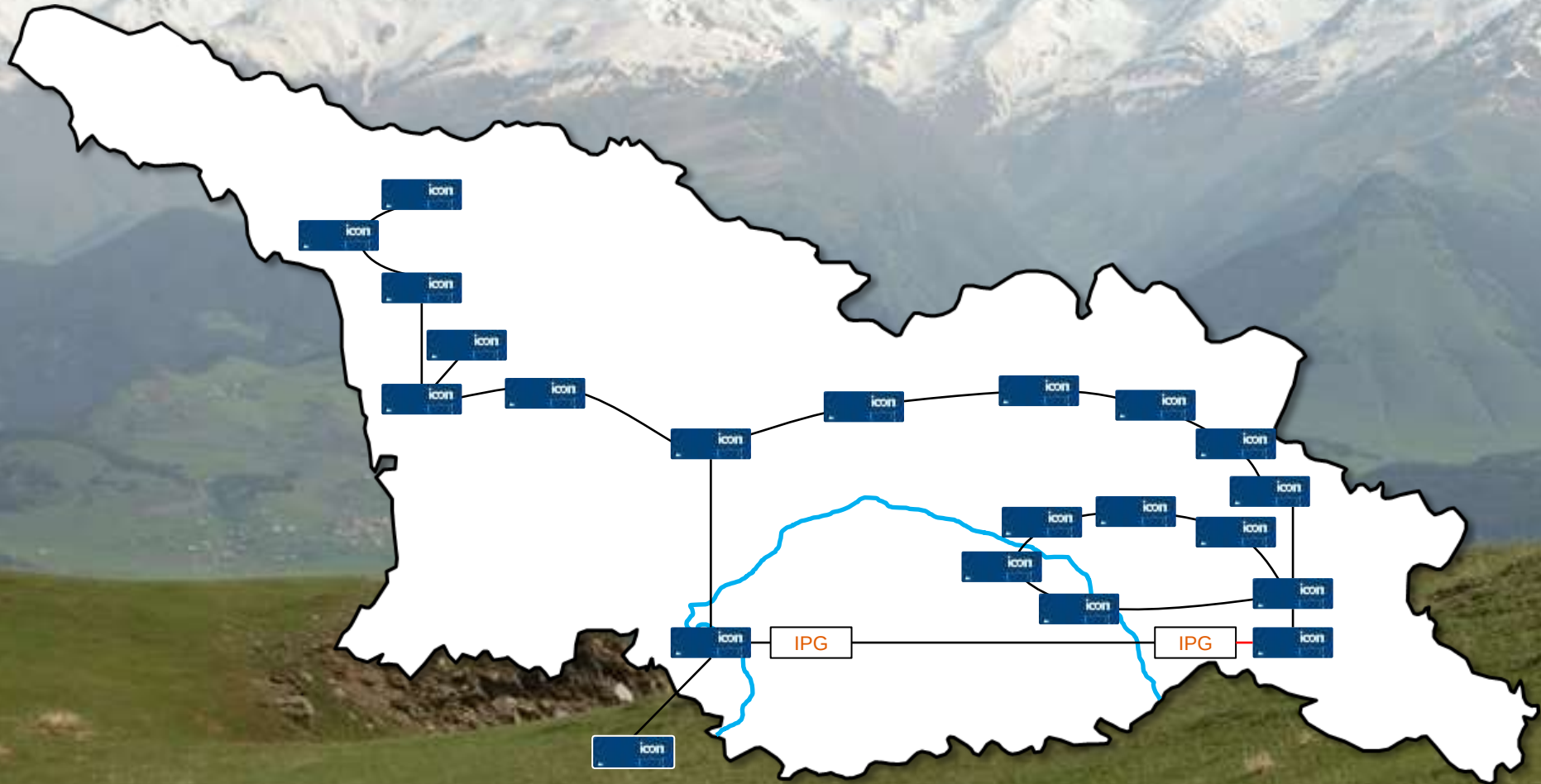


Switches do not provide message delivery statistics

Ethernet Switch was Configured by IT

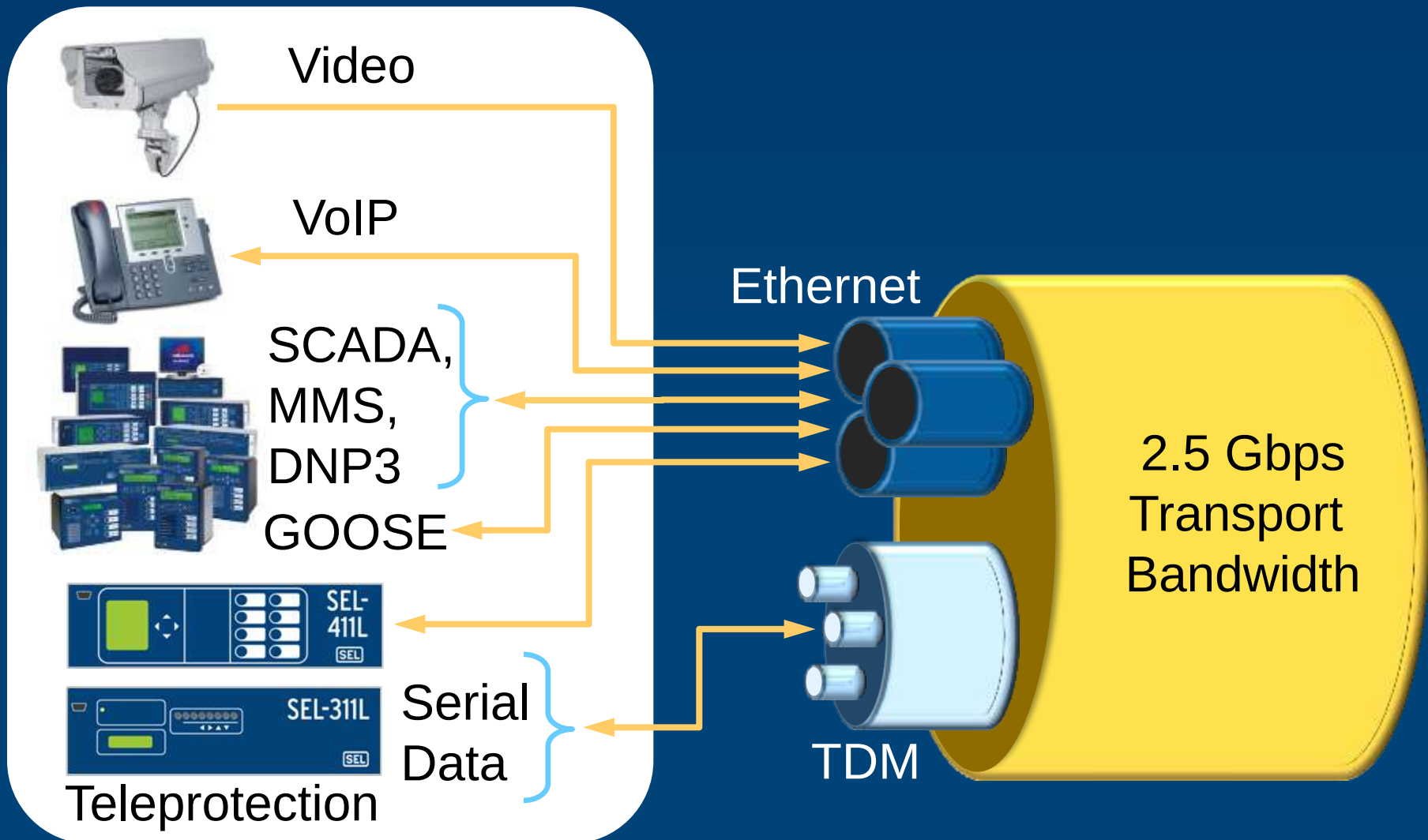
- IT designers had disabled auto-negotiation
- IED could not auto-negotiate to switch but could with direct connect to publisher
- Clause 28 IEEE 802.3u, if auto-negotiation fails, defaults to half-duplex
- Mismatch causes dropped packets at switch port
- Auto-negotiation enabled 100% delivery

Country-Wide WAN supports also Supports LAN for GOOSE

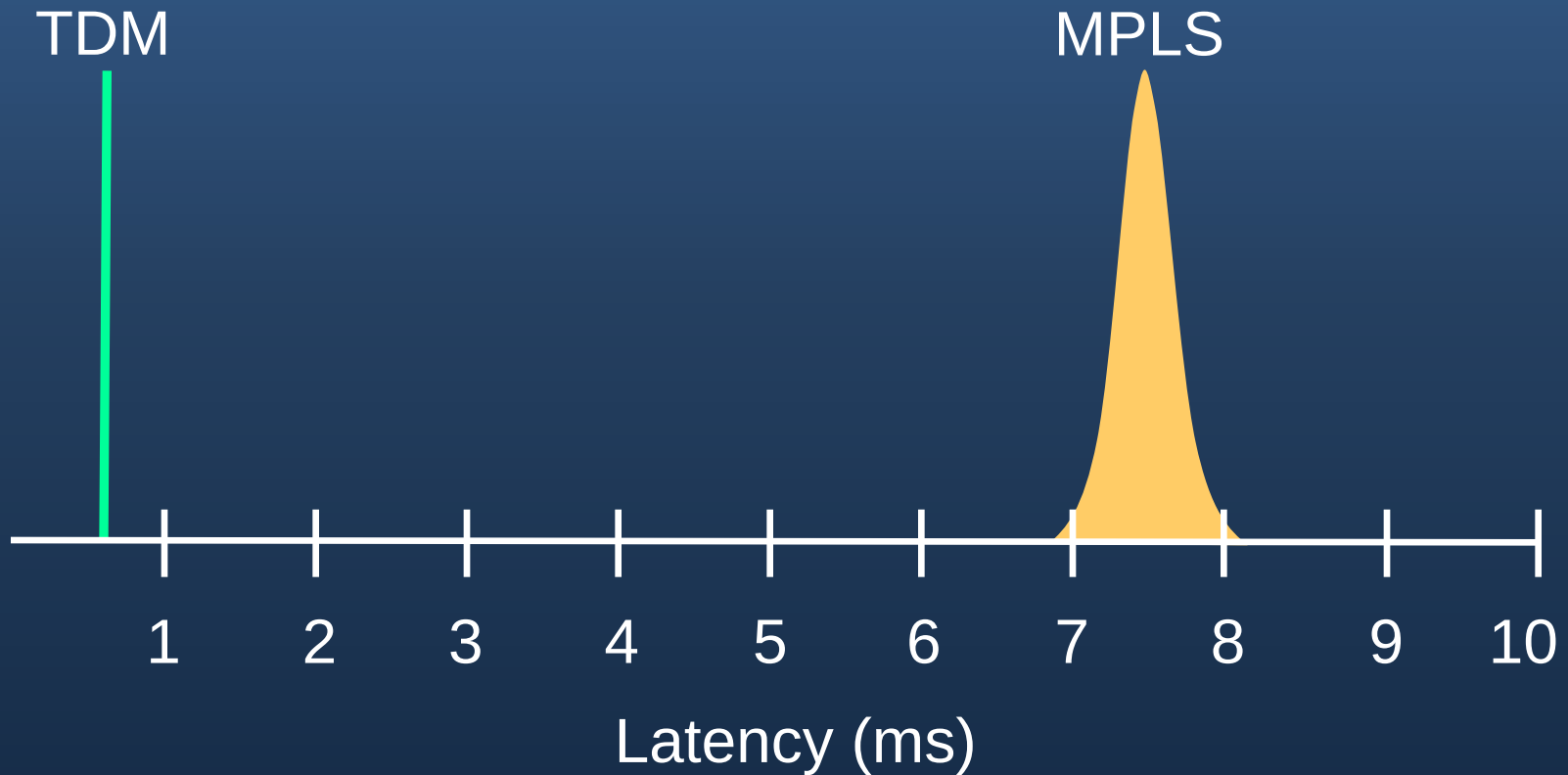


The Best of Both Worlds

TDM and Ethernet



TDM Latency Is Deterministic and Minimal



Trip and Block GOOSE not Always Being Received

=>>goo s 1

SubsID 1

Ctrl Ref: SEL_351A_1CFG/LLN0\$G0\$GOOSE0utPri7

AppID : 4119

From : 07/13/2012 09:15:40.992 To: 07/13/2012 10:26:47.660

Accumulated downtime duration : 0000:00:00

Maximum downtime duration : 0000:00:00

Date & time maximum downtime began : 07/13/2012

Number of messages received out-of-sequence(00S) : 0

Number of time-to-live(TTL) violations detected : 1

Number of messages incorrectly encoded or corrupted: 0

Number of messages lost due to receive overflow : 0

Calculated max. sequential messages lost due to 00S: 0

Calculated number of messages lost due to 00S : 0

TRIP-D



Site C

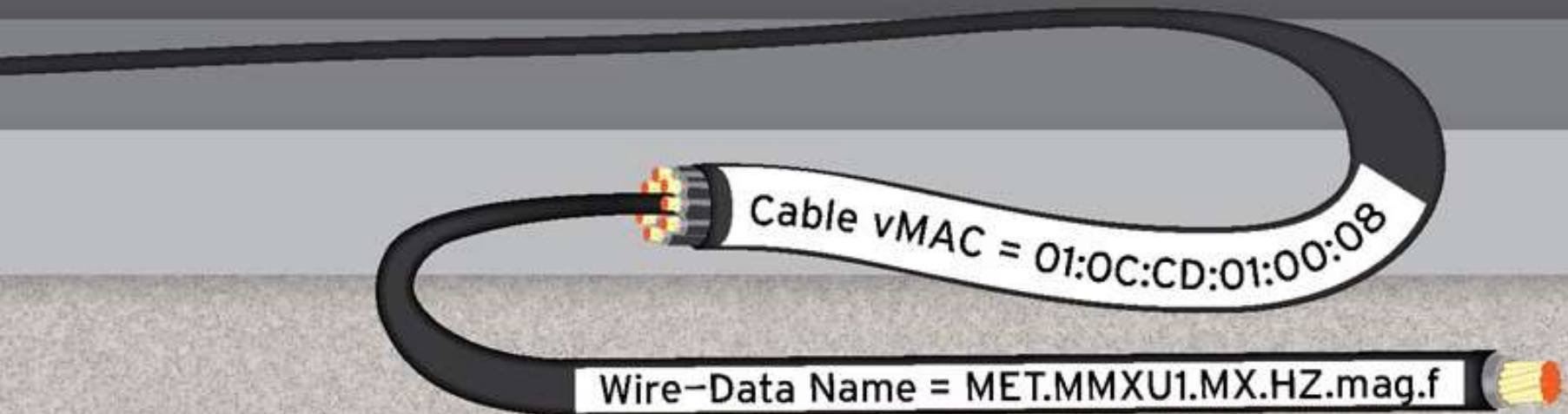


IT WAN Designers Do Not Understand GOOSE

- IT designers plan for throughput – bits/bytes per second
- $(\#GOOSE/second) \times (message\ size) = 144\ byte\ per\ second\ bandwidth$
- However, one GOOSE each second but needs msec delivery
- $(message\ size) / (delivery\ time\ across\ WAN) = 144k\ byte\ per\ second\ bandwidth$
- Also had all GOOSE on shared pipe

QLAN, vMAC, and 61850 Name Document Virtual Cable Tray, Cable, and Wire

Cable Tray QVLAN Name = FDR#1_BF_SWA_PORT12



Document “Virtual Wiring”

Virtual hardwiring “redlines”

Subscriber IED Name	Publisher IED Name	Subscribed Data Item
▶ A_INCOMING_BKR_1	FDR_1	FDR_1.Info_From_FDR_1.PRO.BK1XCBR1.Pos.stVal bit 0
A_INCOMING_BKR_1	FDR_1	FDR_1.Info_From_FDR_1.PRO.BK1XCBR1.Pos.stVal bit 1
A_INCOMING_BKR_1	FDR_1	FDR_1.Info_From_FDR_1.Message Quality bit 0
A_INCOMING_BKR_1	FDR_2	FDR_2.Info_From_FDR_2.PRO.BK1XCBR1.Pos.stVal bit 0
A_INCOMING_BKR_1	FDR_2	FDR_2.Info_From_FDR_2.PRO.BK1XCBR1.Pos.stVal bit 1
A_INCOMING_BKR_1	FDR_2	FDR_2.Info_From_FDR_2.Message Quality bit 0

Virtual Wiring Point List Replaces Physical Wiring Diagrams

Multicast MAC Addr...	App ID	VLAN ID	VLAN Priority	GOOSE ID
01-0C-CD-01-00-20	0020	020	6	FDR_1
01-0C-CD-01-00-20	0020	020	6	FDR_1
01-0C-CD-01-00-20	0020	020	6	FDR_1
01-0C-CD-01-00-30	0030	030	6	FDR_2
01-0C-CD-01-00-30	0030	030	6	FDR_2
01-0C-CD-01-00-30	0030	030	6	FDR_2

Network logistics are the new engineering challenge

OT Switches Configured Like Relays

AcSElerator® QuickSet - [Device Manager]

File Edit View Communications Tools Windows Help Language

Connection Explorer

- Examples
 - SEL-2730M (2)
 - SEL-2730M (3)**
 - SEN13_8PN01ADJAB4R
- TEAM

Device: /SEL-2730M (2)*

Device

- Connection
- Custom Attributes
- Documents
- Permissions
- Settings*
- TEAM

Switch Management

- VLAN Settings**
- RSTP Settings
- Multicast MAC Filtering
- Port Mirroring
- Port Settings

Network Settings

- IP Configuration
- SNMP Settings
- Syslog Settings
- Hosts

Accounts

Security

System

VLAN Settings

VLAN Settings

VL_VID_ST	VL_NAME_ST	VL_TAGGEDPORTS_ST	VL_UNTAGGEDPORTS_ST
1		None	1-24
10	751A_FDR2_	10,11	None
11	421_BKR_B_	10,11	None
901	421_BKR_D_	5, 11	None

Add Edit Delete

Group	Setting	Value	Message
Local User Management Setti...	LOCALUSERS		No local accounts are defined. A device with no local accounts will...
Network Interface Settings	NI_HOSTNAM...		Setting value "" must be 1 to 63 characters long.

Template Palette

- SEL SEL-849
- SEL SEL-2020
- SEL SEL-2030