

Wide Area Protection & Control using High-Speed and Secured Routable –GOOSE (R-GOOSE)

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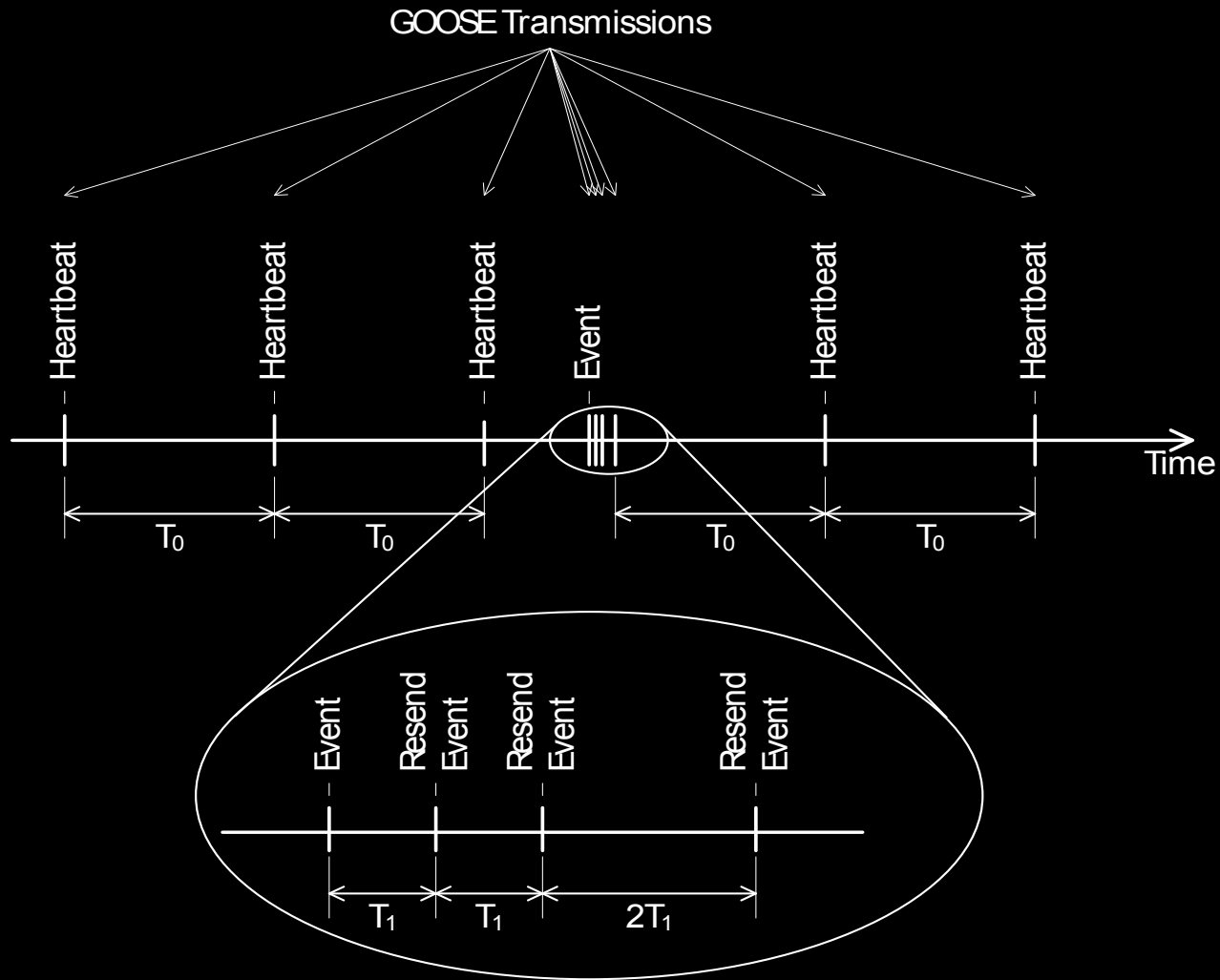
Topics

- GOOSE
- How to Route GOOSE on Wide Area Network?
- Synchrophasors or R-GOOSE
- R-GOOSE based C-RAS
 - Redundancy Considerations
 - Performance requirements
- Cyber Security Implementation
- Lesson's Learned
- Conclusions

GOOSE

- Event Driven
- Data Link Layer / MAC Address Only
 - No IP address
 - No transport (UDP / TCP)
- Multicast (technically broadcast)
- No Handshaking / Acknowledgement

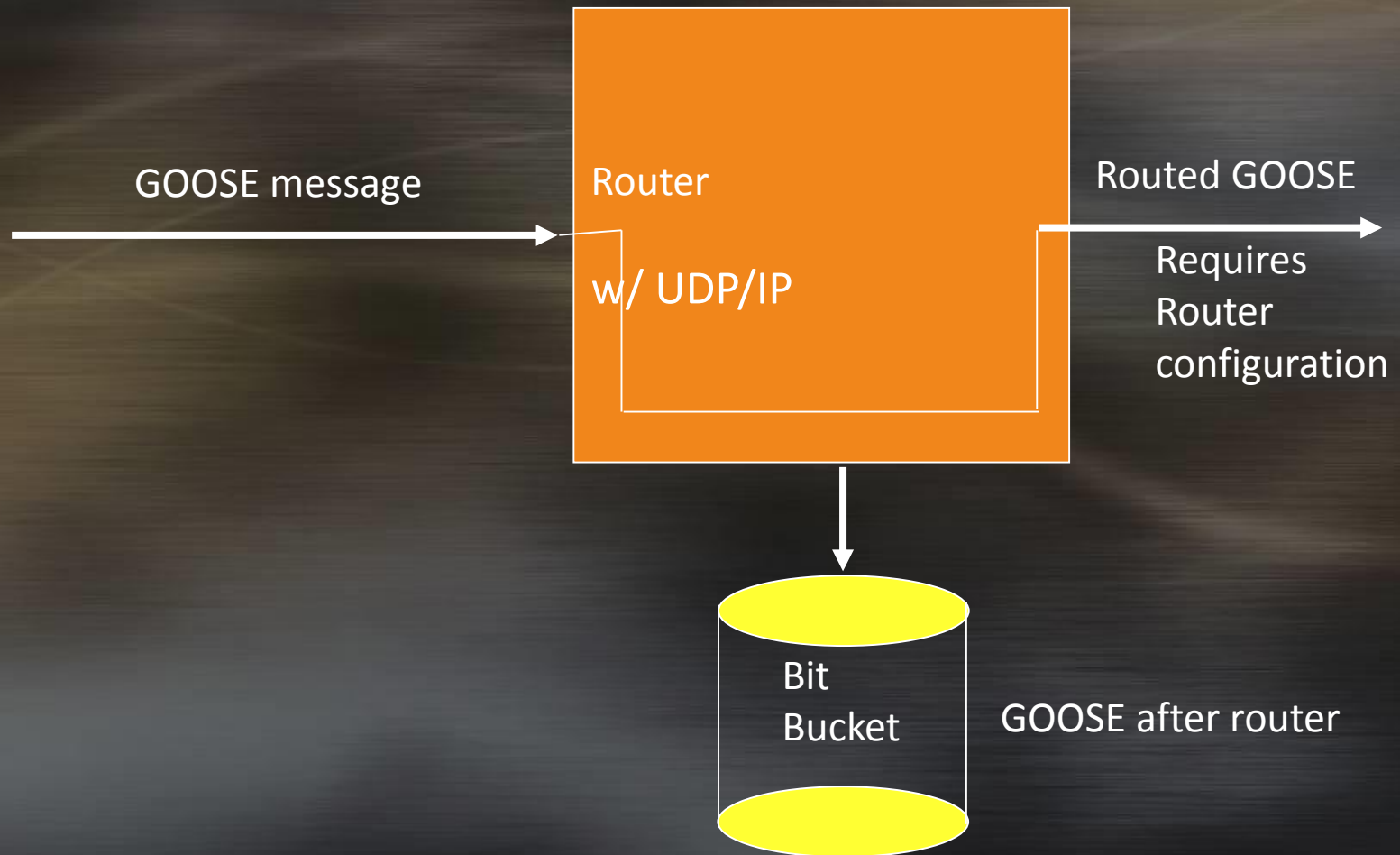
GOOSE Mechanism



T_0 - TxGOOSE UPDATE TIME setting value

T_1 - TxGOOSE1 RETRANS TIME setting value

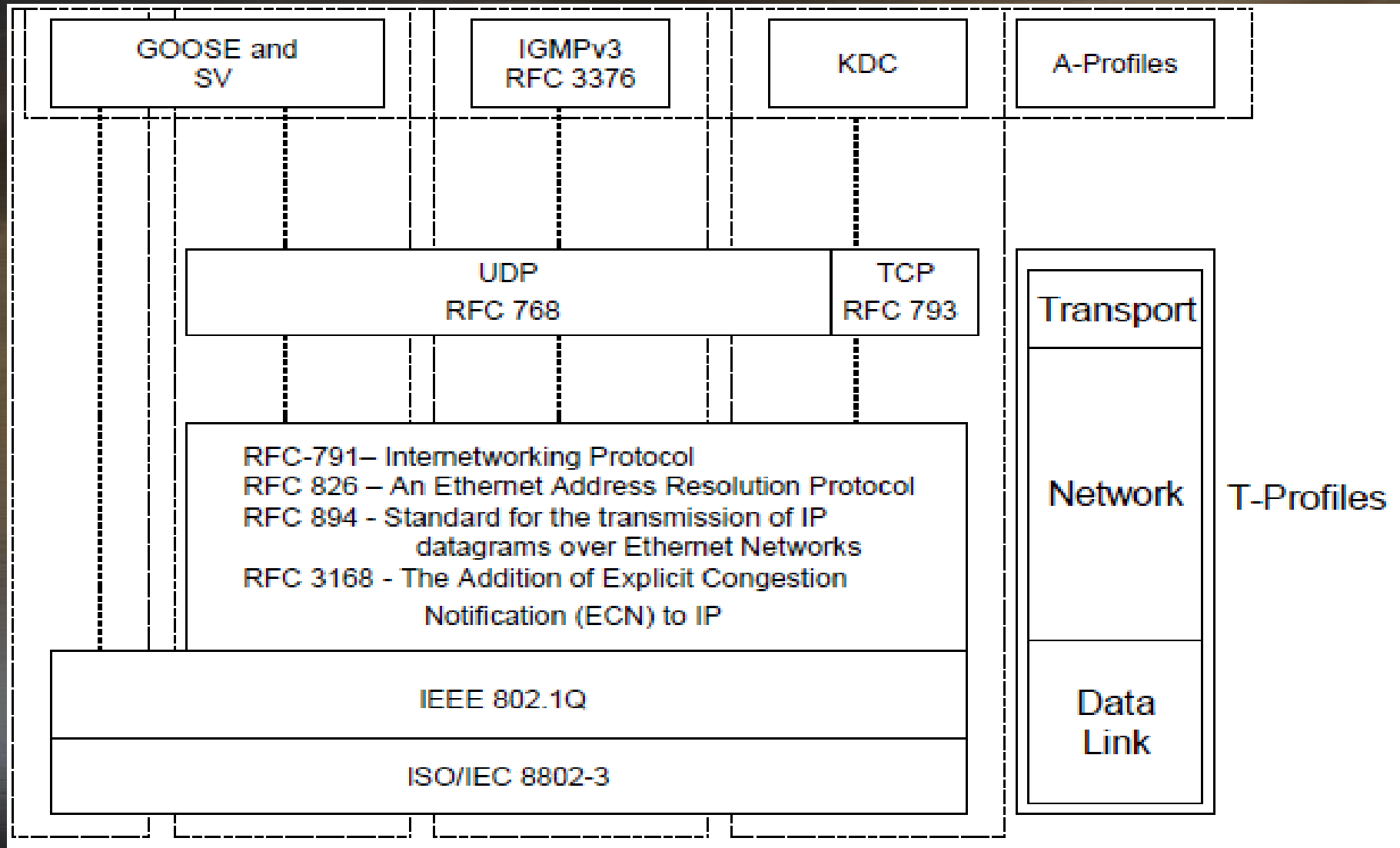
Routing GOOSE



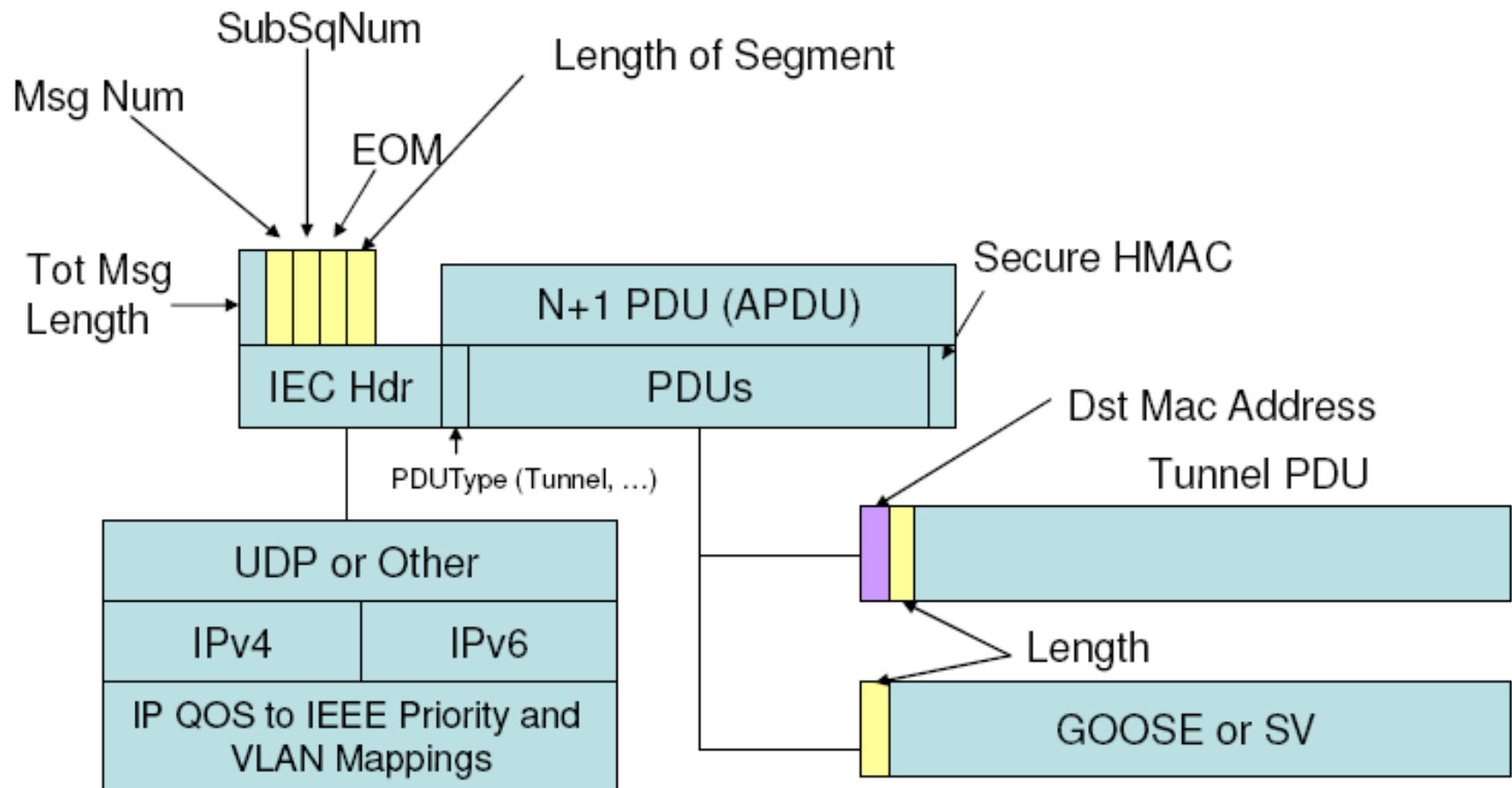
IEC 61850-90-5

- Technical report defining how to map synchrophasors into IEC 61850
- Defines:
 - R-SV
 - R-GOOSE
 - Cyber security

How to Route a GOOSE on WAN?



IEC 61850 90-5 Networked GOOSE/SV



How to Route a GOOSE on WAN?

Attribute name	Attribute type	Value/value range/explanation
PRIORITY	Unsigned8	IEEE 802.Q priority
VID	Unsigned16	VLAN ID
APPID	Unsigned16	As defined in Annex C in IEC 61850-8-1
TransportInUse	Unsigned8	Enumerated value: IPv4, IPv6, and DNS assigned
IPClassOfTraffic	Unsigned8	TypeOfService value or Class of Traffic field
IPv6FlowLabel	Unsigned32	Only with IPv6
IPAddressLength	Unsigned8	4 for IPv4, the value shall be four (4); 16 for IPv6
IPAddress	OCTET-STRING	This attribute shall be 64 octets in size

Application Requirements

- C-RAS (Centralized Remedial Action Scheme)
 - Maintain system reliability by detecting abnormal or predetermined system conditions and taking corrective actions other than fault isolation
 - Synchrophasors? Probably
- Event driven wide area
 - Underfrequency / undervoltage load shedding
 - System state determination
 - Load / generation rejection
 - System separation

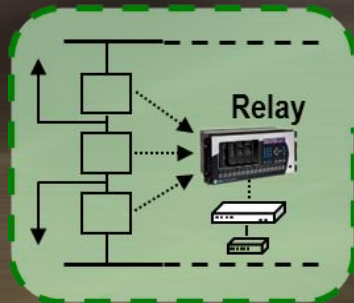
Synchrophasor or R-GOOSE

Parameters	Synchrophasors	R-GOOSE
Publications	IEEE C37.118.1/.2 :2012	IEC TR 61850-90-5 :2012
Communication	Client/Server (IP Unicast)	Publisher/Subscriber (IP Multicast)
Data transmission	Specified rate, 1Hz to 120 Hz	Event-driven (1-2 Hz for no event; retransmission for events)
Data items	Synchrophasors, Analog, Digital	Analog and Digital (status)
Security	No	Key Distribution Center (KDC)
Priority	Regular (due to high data rate)	Higher (Event driven)
Networks	Regular IP/Layer-3 Router	IP/Layer-3 Router with IGMPv3 (firewall to support as well)
Configuration	CFG frames (CFG-1, 2)	ICD, CID files; GET services

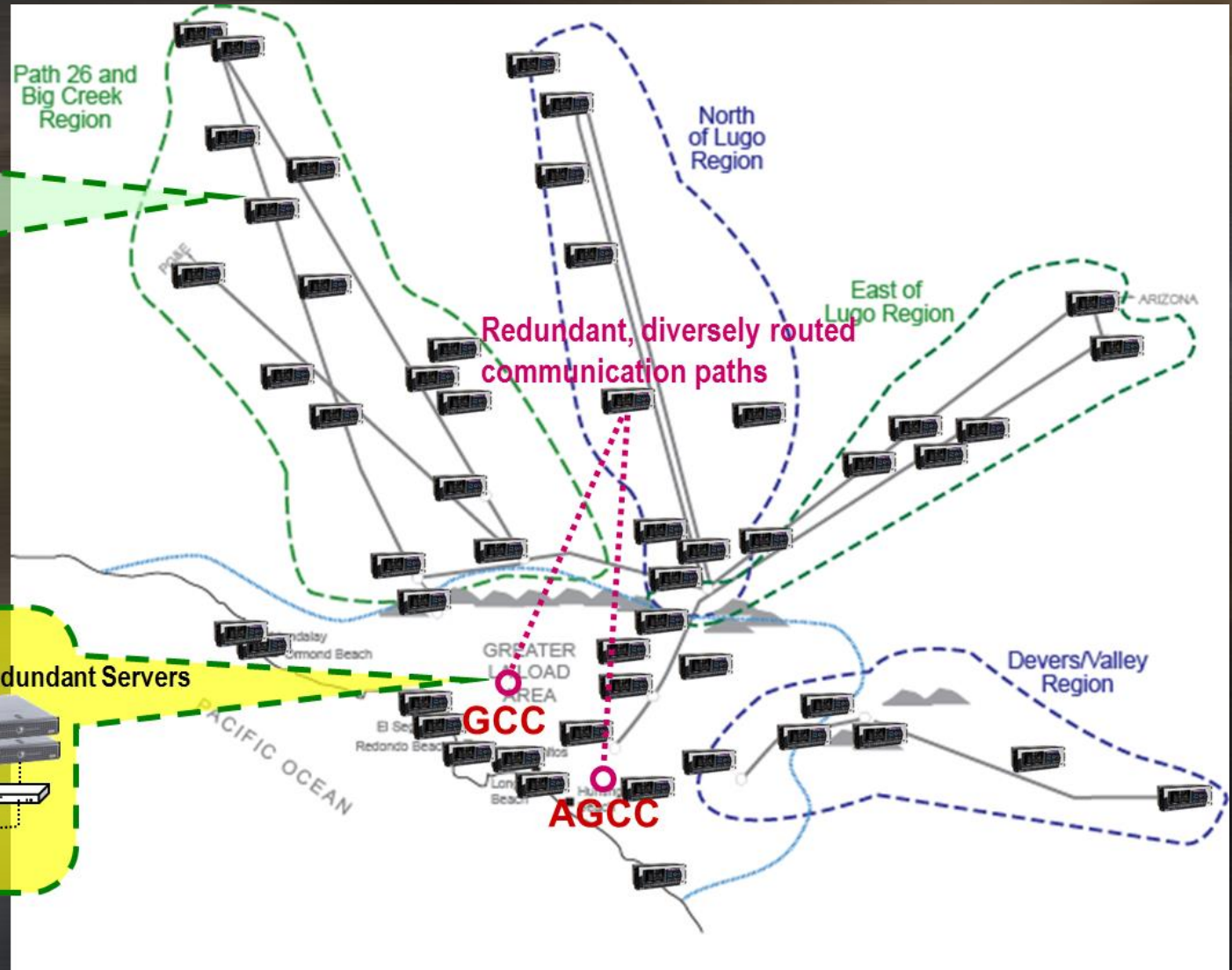
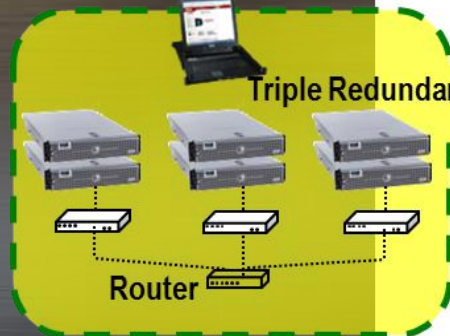
Comparison on Communications

Parameters	Synchrophasors	R-GOOSE
Frame size	100 Byte	100 Byte
Data rate	30 frames/sec	5 frames/sec (worst case-1 event per second per device)
Number of devices transmitting	100 devices	100 devices
Byte Per Second over network	$100 \times 30 \times 100 = 300000$ Bytes/sec	$100 \times 5 \times 100 = 50000$ Bytes/sec (worst case)
Bandwidth requirements	$300000 \times 8 = \underline{2.4\text{Mbps}}$	$50000 \times 8 = \underline{0.4\text{Mbps}}$ (worst case)
Number of locations/devices data received	1	Many (IP multicast)
Storage requirements per Year	$300000 \times 3600 \times 8760 = 9.4$ Tera Bytes	$50000 \times 3600 \times 8760 = 1.6$ Tera Bytes (worst case)
Typical performance requirements	100 milliseconds to few seconds	<10 ms

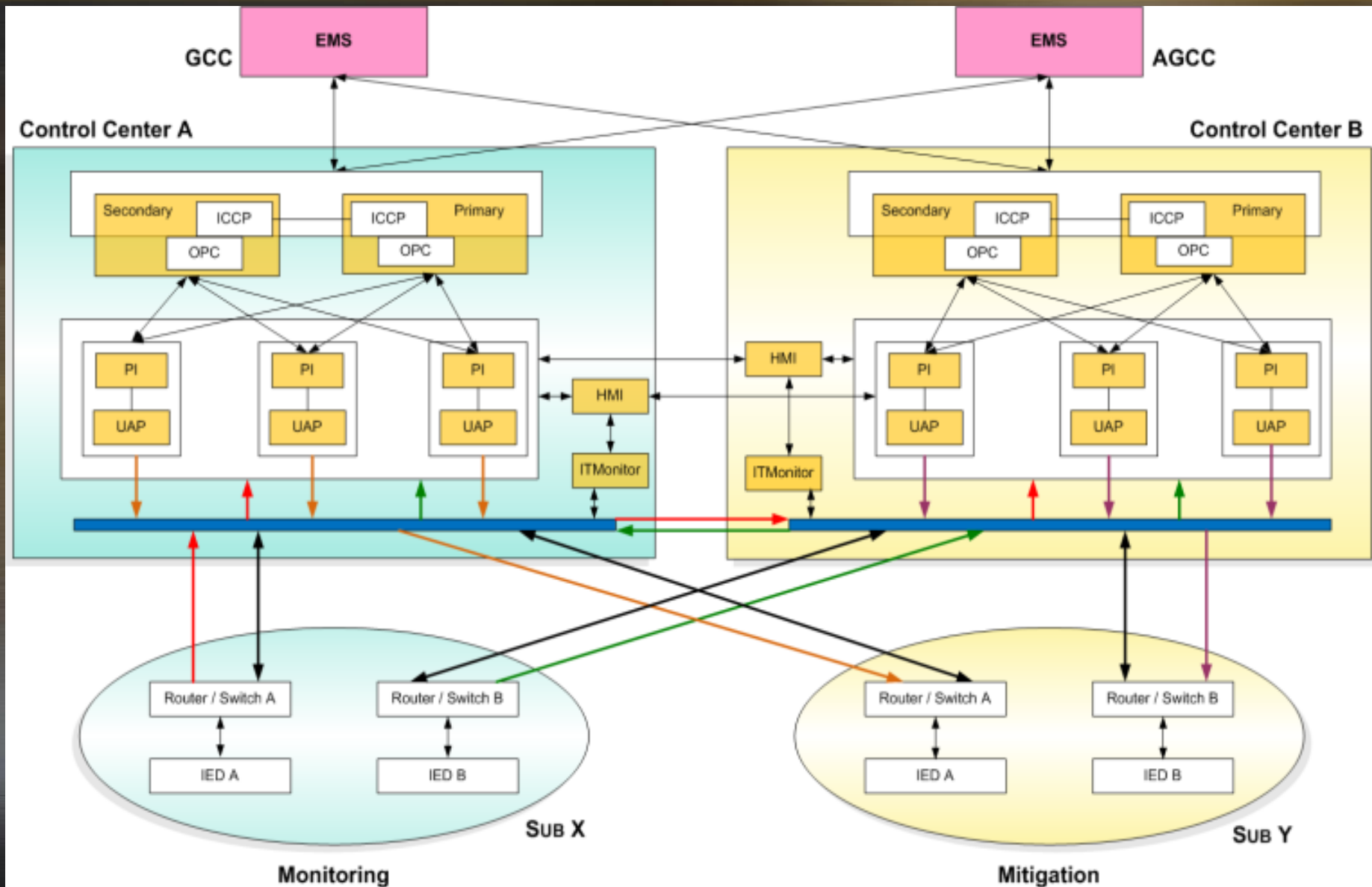
Subs



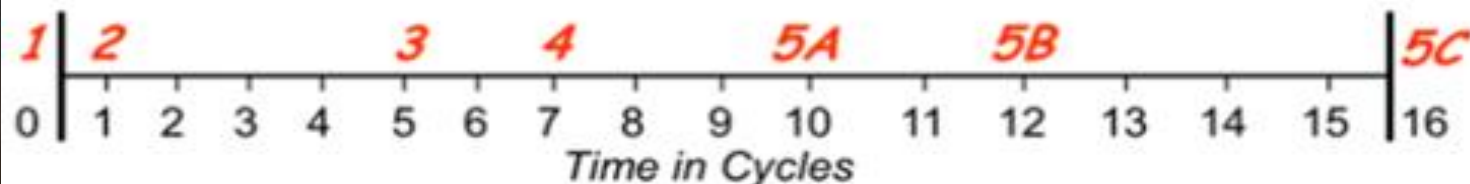
GCC / AGCC



Redundancy Considerations



Performance Requirements



1 cycle = 16.7 milliseconds

	Time	Operational Events
Step 1	@ 0 Cycle	3 Phase Fault on the Bus
Step 2	@ 1 Cycle	Relay Processing time for trip signal to CBs
Step 3	@ 5 Cycles	Open CBs for line/transformer out
Step 4	@ 7 Cycles	RAS Logic Processing for trip signal to CBs to trip generators
Step 5A	@ 10 Cycles	Open CBs associated with 12 generators (I Batch Mitigation)
Step 5B	@ 12 Cycles	Open CBs associated with 4 generators (II Batch Mitigation)
Step 5C	@ 16 Cycles	Open CBs associated with 2 generators (III Batch Mitigation)

Event Detection Fault Clearing:

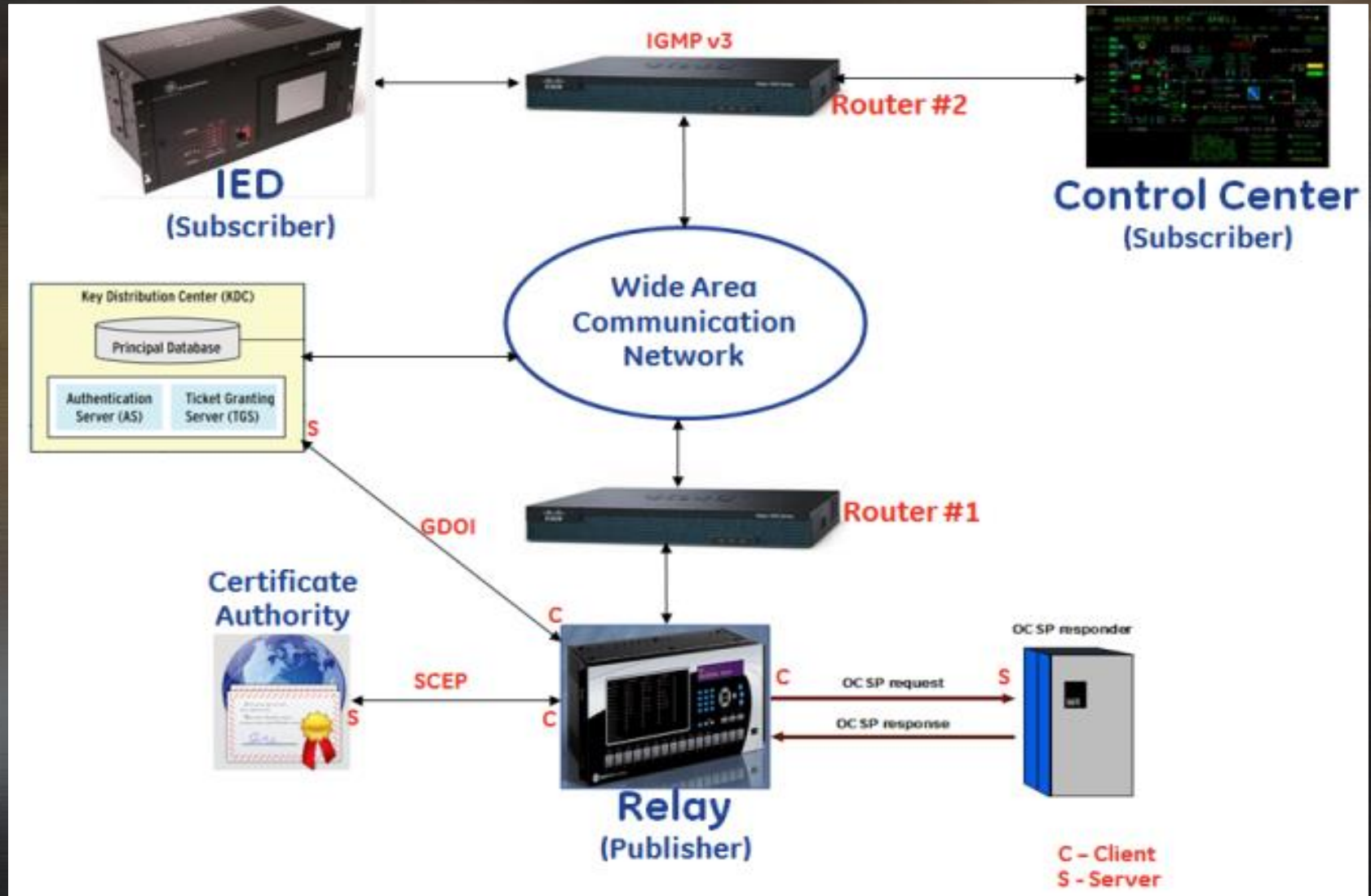
RAS Processing:

Mitigation Generation Tripping / Load Shedding:

Cyber Security Implementations

GDOI: Group Domain of Interpretation (RFC 6407); KDC: Key Distribution Centre

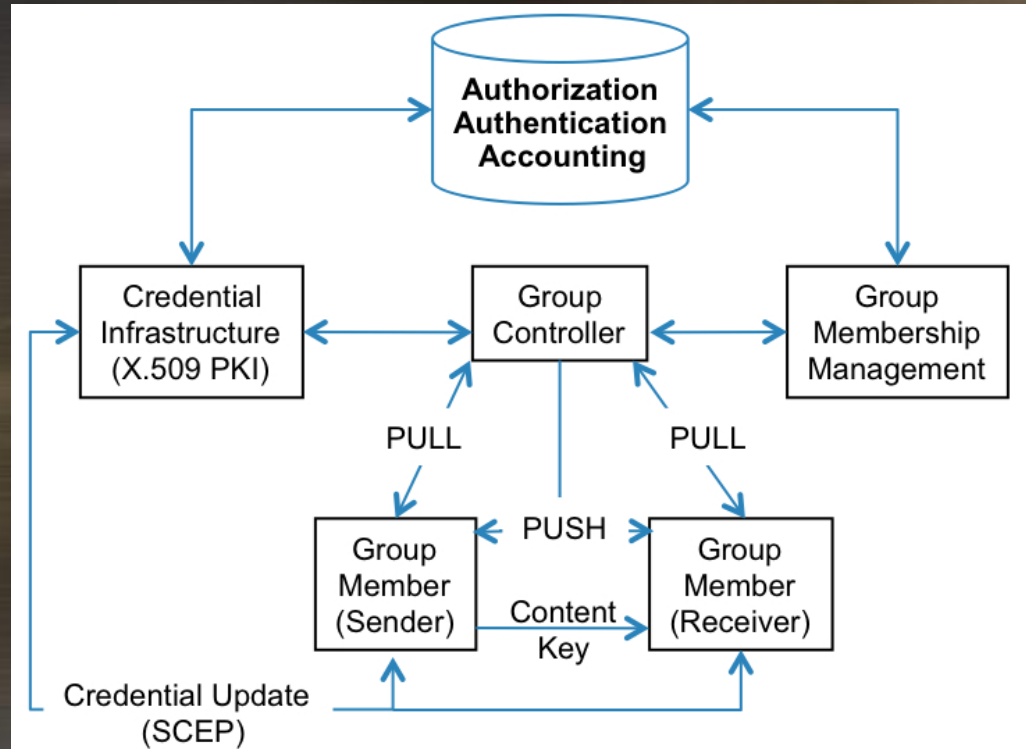
SCEP: Simple Certificate Enrollment Protocol ; OCSP: Online Certificate Status Protocol



Security Definition in 90-5

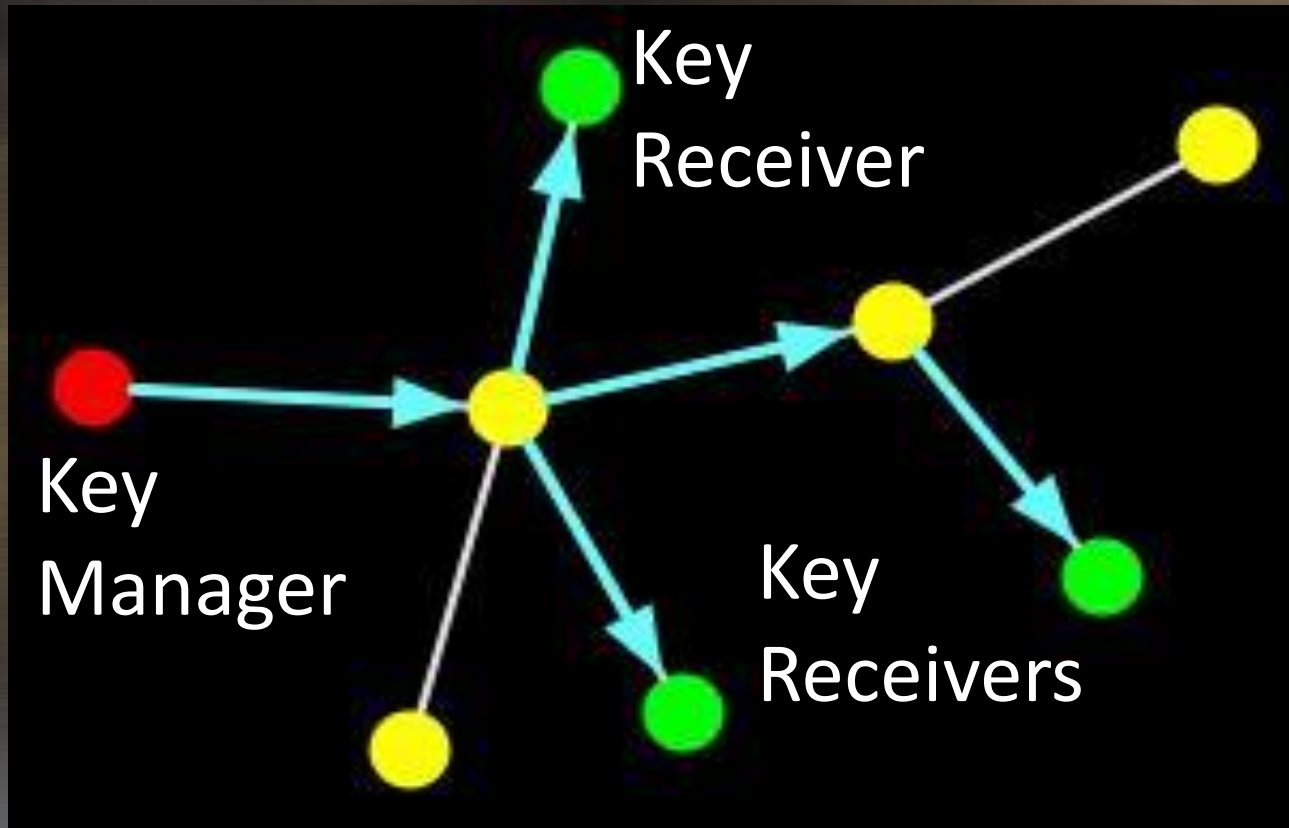
- Defines a Secure Hash Algorithm - SHA2 Hash code for message authentication / integrity
- Defines AES as the encryption algorithm
- Identifies / Extends a Key management system
 - Group Domain of Interpretation
 - The publisher manages the keys to all subscribers
 - Same key for Hash and Encryption

Group Domain of Interpretation - GDOI



- Publishers act as Controllers
- Receiving Group Members “Pull” new keys
- Centralized Authorization Management

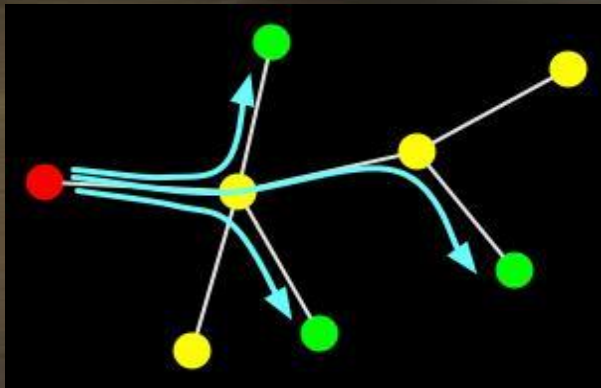
Publisher-Based Key Management



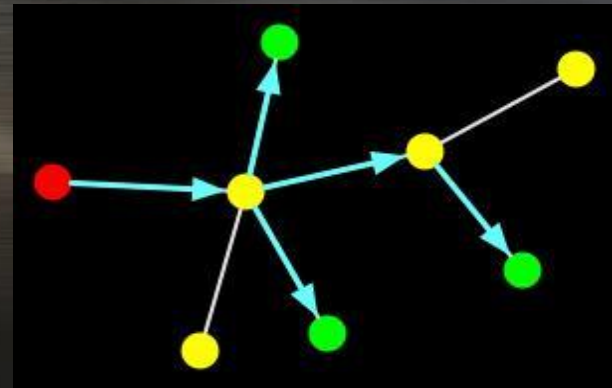
Keys are dynamically managed
Changed when a Subscriber is removed

Unicast vs. Multicast

Point-to-Point
Multiple Streams

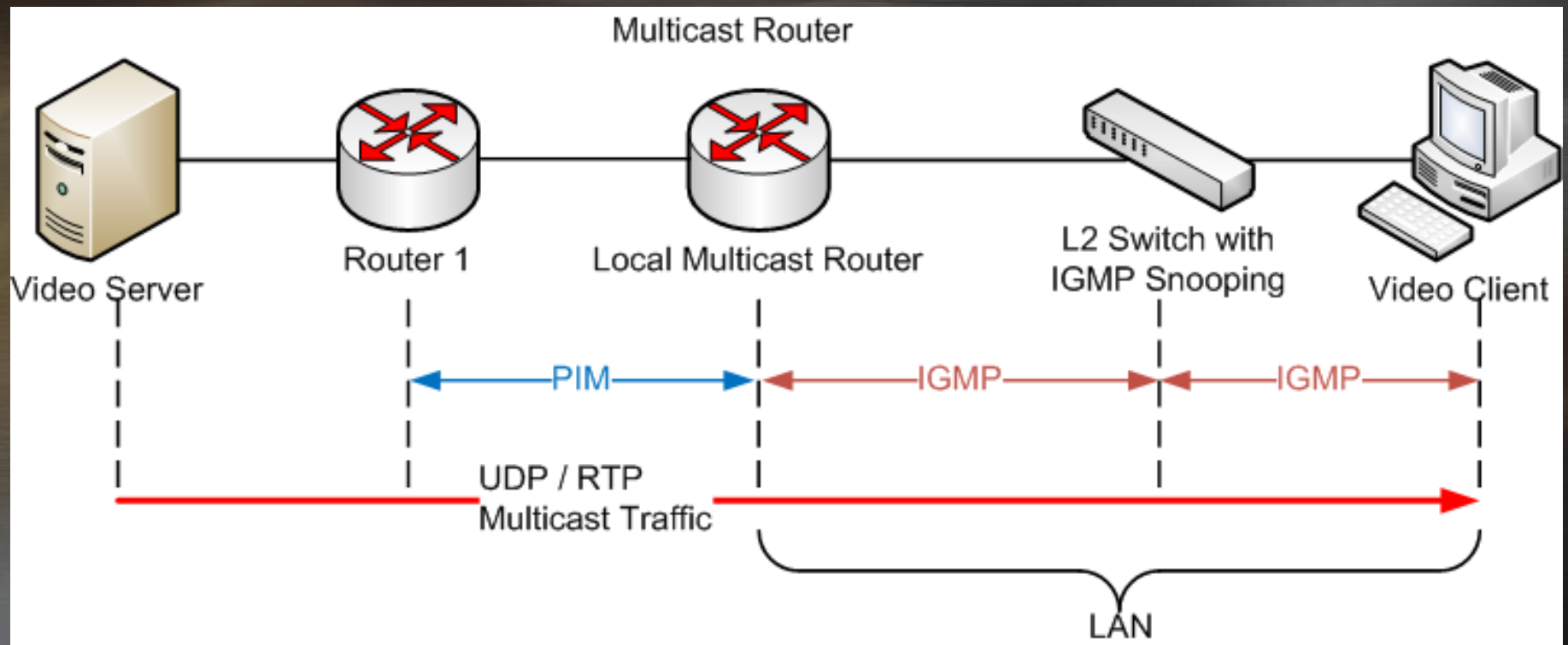


Multicast
One Output Stream



Why IGMP matters?

Multicast Path Establishment via Internet Gateway Management Protocol – IGMP



Lesson's Learned

- Requirements right from planning stage
 - Redundancy
 - Cyber security
 - Performance
 - Remote testing
- Utility communication network
 - Segregate traffic of R-GOOSE and Management
 - Bandwidth requirements to meet performance
 - Firewall not blocking IGMPv3 traffic
- Implementation agreement and technical workshops are useful for high-tech projects

Conclusions

- Industry recognized mechanism, GOOSE can be implemented over Wide Area Network
 - IEC TR 61850-90-5 defines R-GOOSE protocol
- High-speed R-GOOSE can be achieved for WAPC if dedicated network is designed
 - Priority tagging, VLAN, IP Class of Traffic
- Security mechanisms supported by R-GOOSE
 - Key Distribution Center
 - Consider Infrastructure to be supported
- Synchrophasors or R-GOOSE for WAPC >>
Select per application & network requirements

Thank You

Questions?