Practical Communication Considerations for Protection Engineers

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Communications Basics

- Goal: Transfer Information
  - Earliest “Written” Forms
    - Cave paintings
    - Petroglyphs
    - Pictograms
    - Ideograms
    - Alphabet- delivered by couriers
- Characteristics
  - Not time sensitive
  - Historical record
  - Describes events
  - Communicates laws/decrees

Communications Basics

- Types of Data at a Substation:
  - Metering
    - Watts-VARs-Volts-Amps-Harmonics
    - System State Information
  - Relay Protection
    - In-substation: Transformer Differential
    - Extra-substation: Line Relaying
  - Control-SCADA
    - TRIP-CLOSE
    - SPS
  - Information
    - Status
    - Events

Communications Basics

- Goal: Transfer Information-Substations
  - Not time critical
  - Time critical
- Not Time Critical
  - Event data
  - Metering information
  - Condition-based monitoring
  - Synchrophasors
- Time Critical
  - Protection & Control
  - Synchrophasors?

Performance Requirements: Communications Considerations

- Two delivery methods:
  - Time Division Multiplexing
  - Packet-based Networks

- Both are:
  - “Digital” 1’s and 0’s data
  - Potentially reliable delivery methods
  - “Multi-media”: Fiber, copper, wireless
  - Available on leased or private networks

Performance Requirements: Communications Considerations

- Types of Circuits
  - Serial
    - Analog
      - Four Wire AC Data
      - POTS
    - Digital
      - RS-232
      - RS-485
      - C37.94
      - IRIG-B
  - Packet Transport Methods (Data & VoIP)
    - Frame Relay
    - MPLS
    - Carrier Ethernet

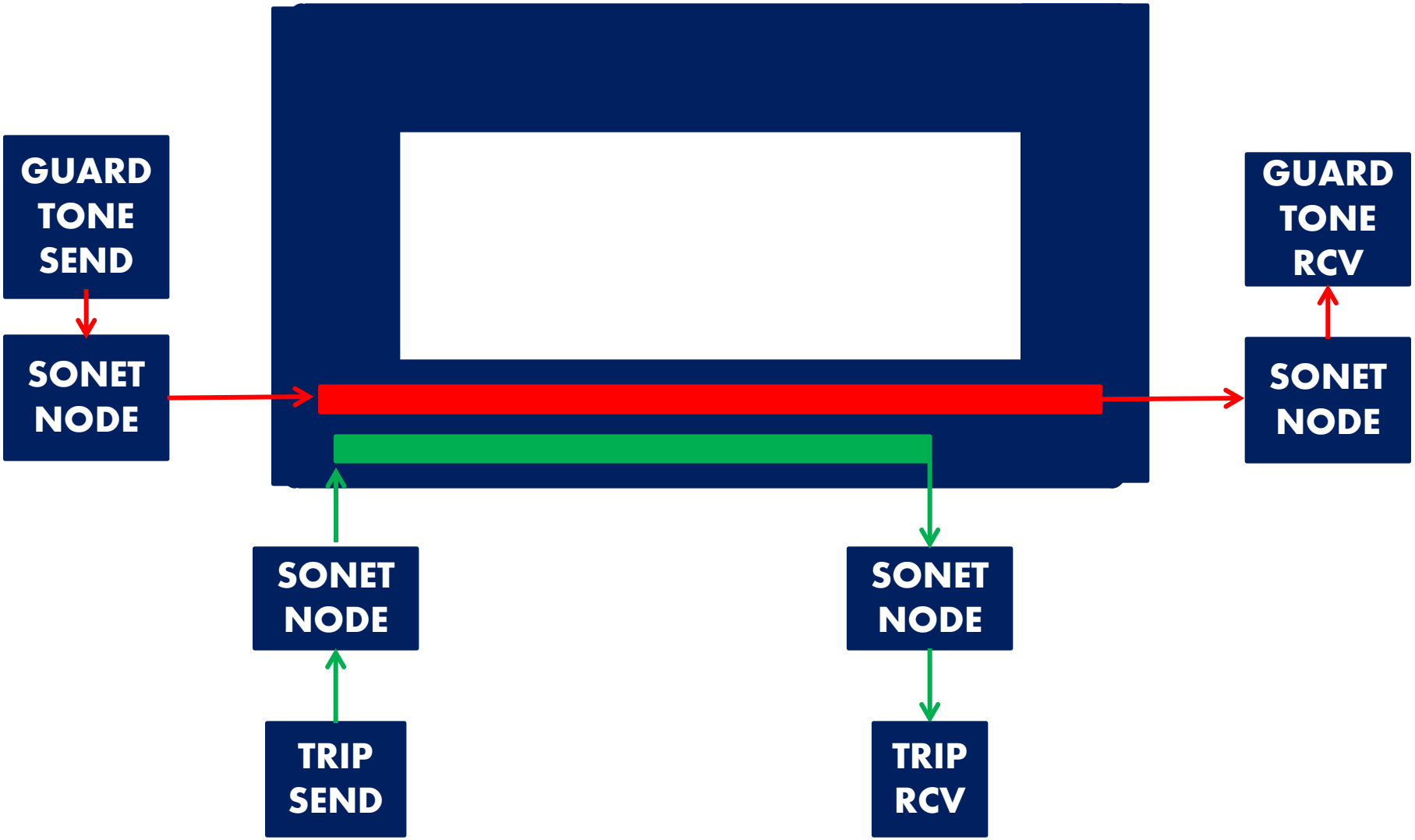
Performance Requirements: Communications Considerations

- Characteristics of Serial Circuits
  - Native to TDM networks such as SONET
  - Deterministic and predictable performance when carried on TDM networks
  - Reliability impacted by cabling methods and network path/choice
  - Fixed & dedicated bandwidth
  - Port speed and framing settings required
  - Point-to-Point or Point-to-Multipoint
  - Being replaced by packet-based connections

Transporting Serial Circuits Natively

- Time Division Multiplexed Networks/Ring Topologies
- DS-0 basic building block at 64 kbps
- 24 x DS-0 = one T-1/DS-1 at 1.544 Mbps
- 28 T-1/DS-1 = one STS-1 (copper) or an OC-1 (optical)
- One STS-1/OC-1 roughly 50 Mbps bandwidth
- Bandwidth can be channelized or “Bulk” for IP traffic
- Protection-Class TDM networks switching <= 5 ms
  - SONET Standard Core switching <=50ms

TDM Communication Circuit: TDM/SONET



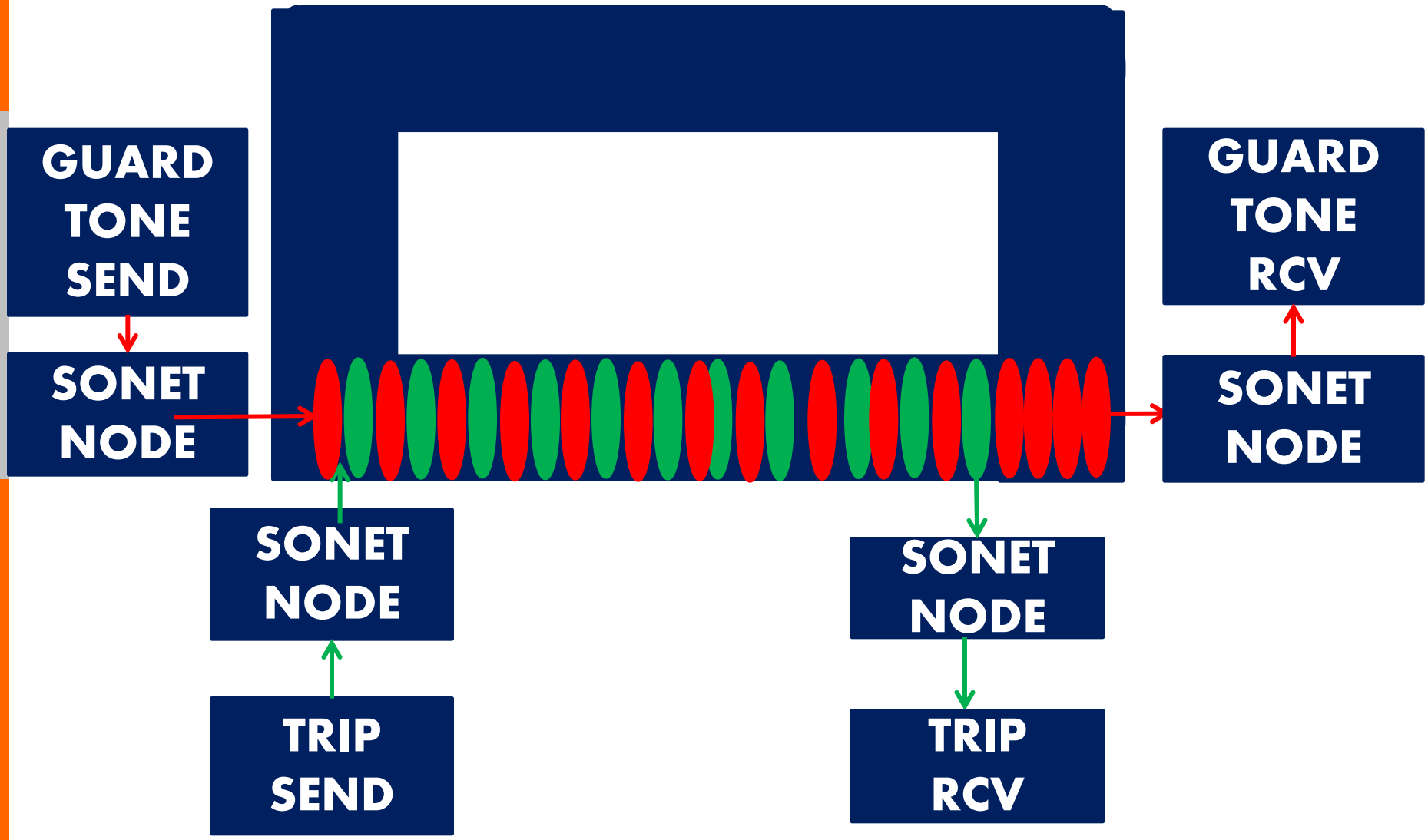
Packet-based Networks

- Originally developed to transport files between computers
- Progressing toward SONET-like performance
- Bandwidth not dedicated; ‘best effort’ delivery
- Subject to additional NERC-CIP/Cyber Security scrutiny
- Not “Plug and Play”
- MPLS and Carrier Ethernet replacing ATM and Frame Relay packet-based networks

Performance Requirements: Communications Considerations

- Characteristics of Ethernet Circuits
  - Per ‘application’, higher potential bandwidth than serial circuits
  - Bandwidth dependent on IED processor speed
  - Bandwidth can be shared with other applications
  - “Best-effort” data delivery
  - Increasing Cyber Security hurdles
  - May require close coordination with IT staff
  - Point-to-point : multipoint-to-multipoint

TDM Communication Circuit: Packet Delivery



Ethernet Over SONET

- SONET networks can carry Ethernet very efficiently
- Non-routed networks (“Layer 2”) transported over TDM
- Ethernet bandwidth can be separated into separate pipes of dedicated bandwidth
- Can be a NERC-CIP friendly approach for one network to carry secure and non-secure data
- The IT-Telecom world is quickly embracing Packet-based networks and replacing TDM networks

Transporting Serial Circuits Over Ethernet

- Serial Circuits can be packetized for Ethernet transport
- Typical serial packetization occurs at the T-1 level
- Called “Pseudowire” (RFC 3985)
- Consumes more than a T1’s worth of bandwidth
- Circuits potentially subject to performance issues due to
  - Jitter
  - Asymmetrical network delays
  - “Long” network switching times
  - Lack of hardening to IEEE-1613 specs

Basic Types of Ethernet Networks

- “Legacy”, using Spanning Tree or Rapid Spanning Tree network discovery and healing
  - Many business-class networks built with this topology
  - Seconds up to minutes of restoration depending on network size
- Multiprotocol Label Switching
  - Designer can force priority and switched circuit routes (SONET-like in performance)
- Carrier Ethernet
  - Can carve out virtual dedicated IP bandwidth between node locations

IT Paradigms

- Design networks for end user mobility
- Design networks to handle multiple types of traffic
- Design networks with VPN tunnels but not for operational needs
- Design networks which have multiple restorative paths (MESH topologies may be “ideal” for IT)
- Design networks that can support multiple priorities of traffic delivery (video streaming, VoIP, et al)
- Nice air conditioned rooms, filtered power sources

IT Paradigms

- “Fast” switching time is ‘as good as SONET’…

  …the Telecom-Class SONET <=50 ms
- Substations are remote data centers, with air-conditioning, anti-static floors, conditioned power
- Substations have a single point ground bus bar to which all metallic elements in the control house are bonded
- The single point ground bus bar only has one earthing connection
- Restoring a broken router can wait until normal business hours

Keys to Practical Substation-Class Network Design… for the P&C and SCADA Engineer

1. Catalog all known circuit types at a substation
2. List maximum tolerable latency for each circuit type
3. List maximum tolerable restoration time for a data network switching event for each circuit type
4. Develop Service Level Agreement Document listing:
   - Lead time for new site network connections
   - Lead time to retrofit existing sites with new services
   - Expectations on IT-led UPS/DC Plant maintenance
5. Attend & actively participate in UTC events – (what you don't know might hurt you)

Keys to Practical Substation-Class Network Design…for the IT-Telecom Architect or Engineer

1. At a minimum, specify IEEE-1613 compliant network devices
2. Substation devices do not get powered by 120V AC
3. Welcome vendors that were birthed supplying equipment for substation applications… then buy their equipment
4. Be aware that a network switching time of less than 5 ms is possible
5. The P&C and SCADA engineers are your customers
6. Attend the Georgia Tech PRC and listen. Buy equipment designed for substation use

Questions…

Together, we can have a cost effective, secure, reliable, dependable, smart, and safe electric system

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