Wide Area Monitoring and Control

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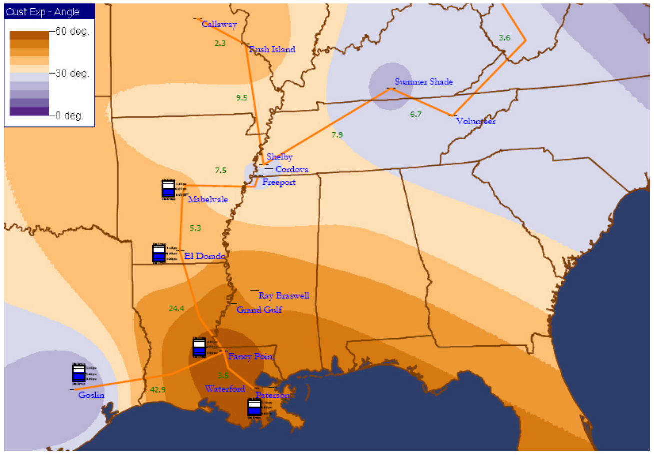
Introduction - terminology



- What many utilities are building now by gathering synchrophasors –

Wide area monitoring (WAM)

- In the future when the automatic control loop is closed –

Wide area monitoring, protection, automation, and control (WAMPAC)

WAMPAC drivers

- Major blackouts show need for better monitoring, situational awareness.
- Post mortem analysis shows how closed loop control could save the system.
- Protection of stressed network is tough with today’s local methods
- We need experience to trust closed loop wide area control algorithms
- Open loop WAM will lead to control development and testing

What exists today?

- SCADA monitoring and control
  - Unsynchronized local measurements every few seconds.
  - Manual control in seconds.
  - Quasi steady state WAM and control
- EMS – updates in minutes
  - State estimation - minutes
  - Contingency analysis - minutes
  - Dispatch, commitment, facility loading
- Remedial action scheme (RAS) or SIPS
  - High speed measurement and control – 100 ms
  - Dedicated scheme for protection against a specific foreseen problem

These will be absorbed some day…

Transmission Smart Grid functions

- Integrated centralized state presentation for decision support
- Fault, disturbance, event data gathering & presentation
- Primary power apparatus condition and operation monitoring

These are all monitoring similar to today, but higher bandwidth, completeness, quality matter…

Transmission Smart Grid functions

- Centralized high-speed measurement *and closed loop control* to protect wide area grid against disturbances, outages, faults, & failures.
  - Automatic high speed remediation of contingencies - many flexible RASs.
  - Clearing faults or preventing loss of stability via regional measurements and tripping.
  - Mitigation of DER operating issues -
    - Islanding
    - Faults not detected by substation relays or other protective measuring devices.

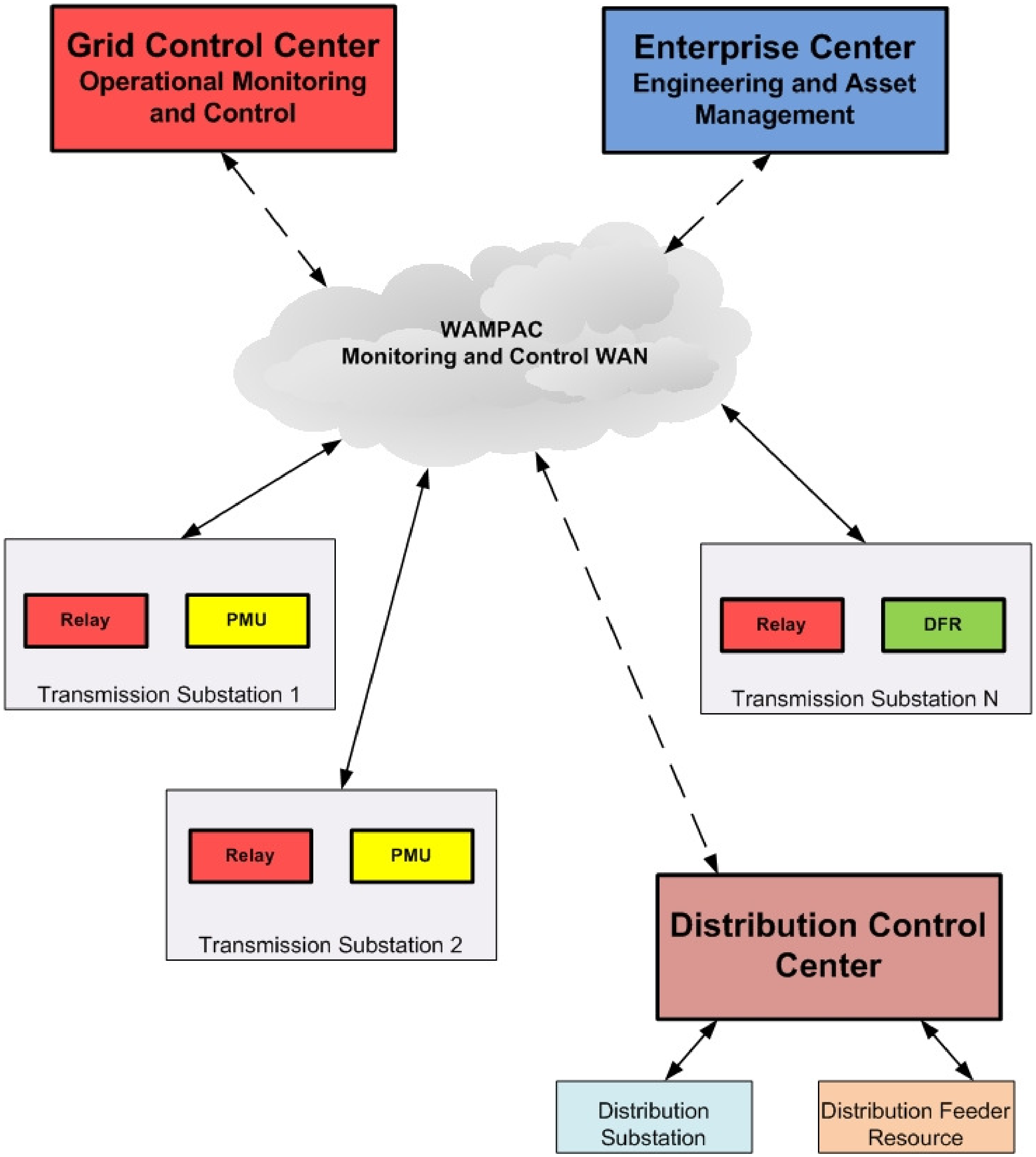
Transmission Smart Grid functions

- Integrated *closed loop control* of power electronic and static power control devices –
  - SVCs
  - STATCOMs
  - UPCs
  - UPS
  - Energy storage systems
  - Dc converter interfaces
  - VFTs
  - Static capacitor and reactor banks.

Basic WAMPAC architecture

- Centralized like human nervous system
- Real time periodic substation data
  - Time synchronized electrical measurements
  - Boolean state values
- Background record gathering
- High speed control (relaying times)

Basic WAMPAC architecture

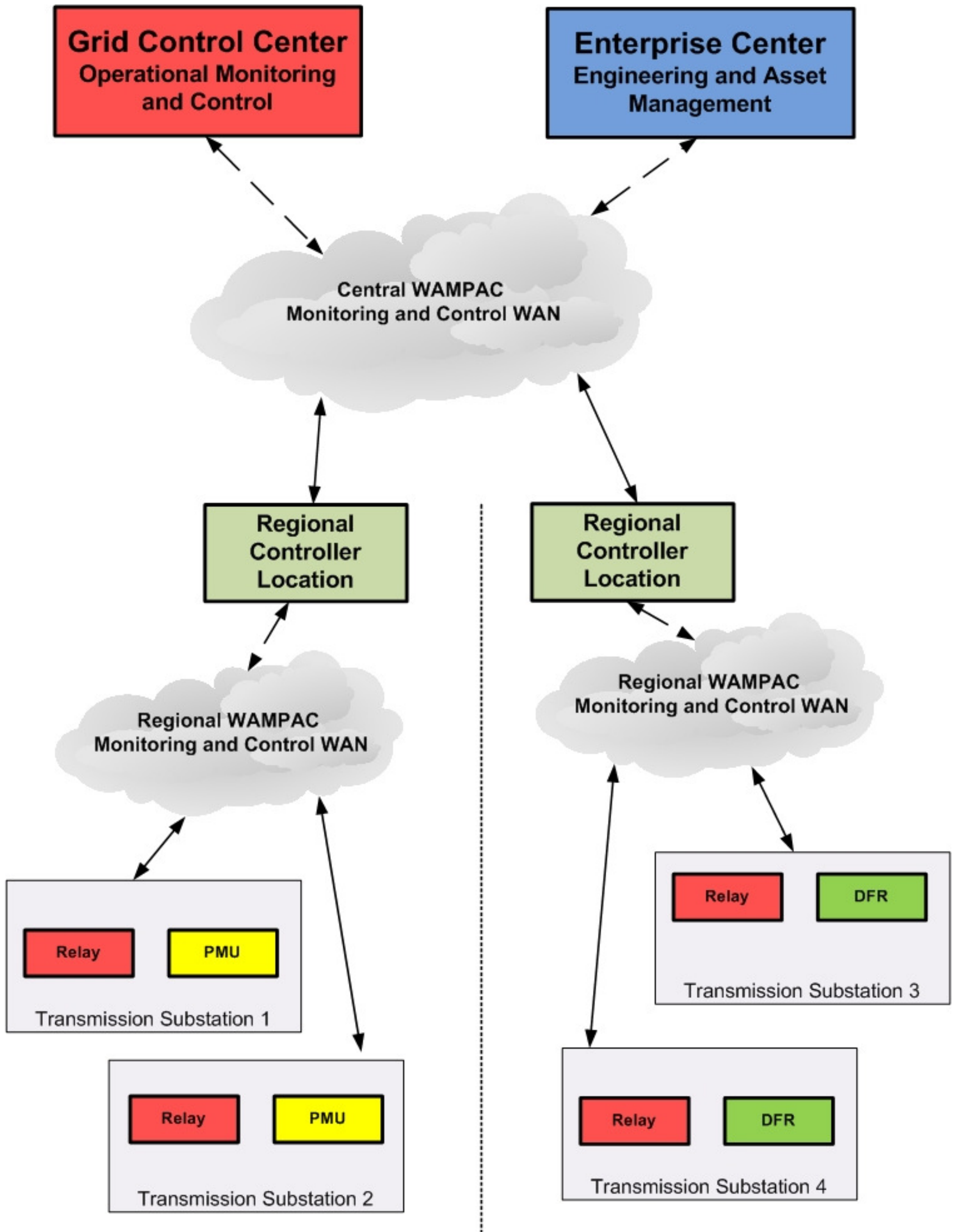


- Substation data gathering systems
- IEC 61850 process bus
- WAN
- System level devices and systems
- Reduced demands at distribution stations

Hierarchical WAMPAC architecture

- Highest speed processing and fastest control for a limited region
- Distill/aggregate data for top level controllers, historians, enterprise systems
- Store details locally and upload only what is interesting
- Slower wide area control – multiple communications hops

Hierarchical WAMPAC architecture



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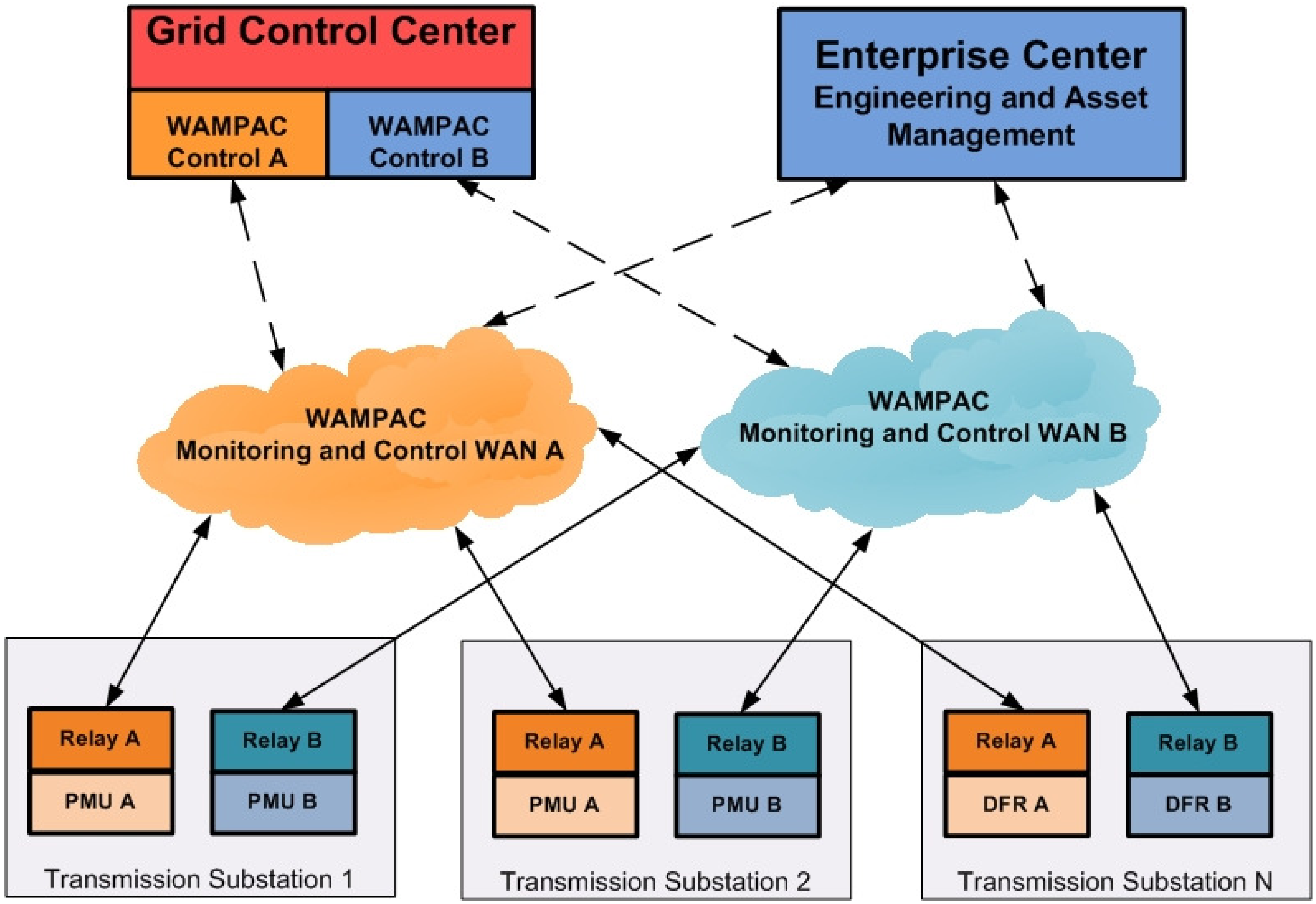
Redundant WAMPAC architecture

- Critical closed loop protection of the entire grid
- Single point WAMPAC equipment failures cannot disable any function
- Additional redundancy needed for less reliable components
- Additional redundancy needed for practical maintenance and repair

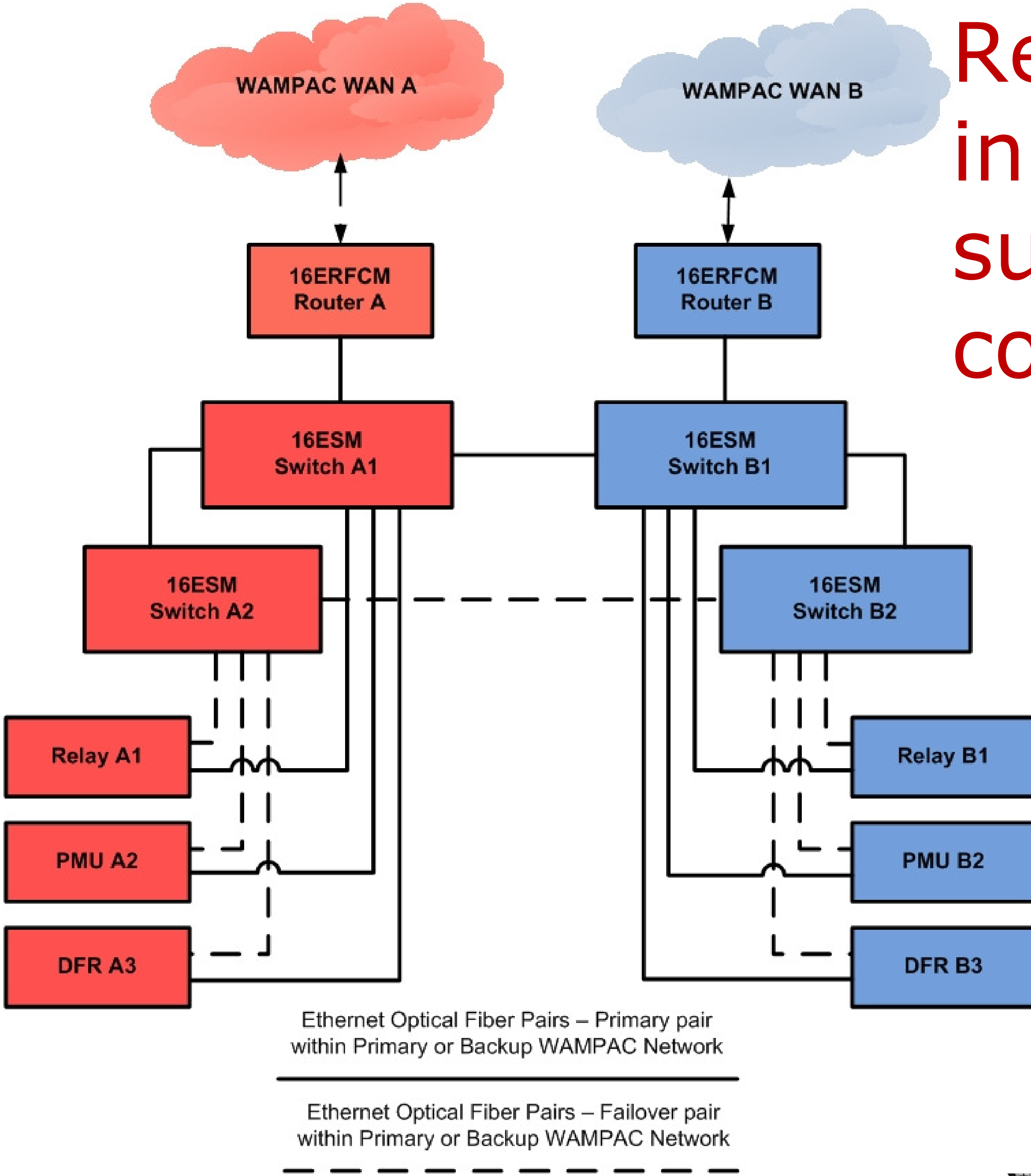
Redundant WAMPAC architecture



Redundant WAMPAC architecture

- Isolated communications
- Two control centers
- Added redundancy or voting within central controllers and computers
- Redundant relays in substations for control
- Redundant measuring IEDs or relays for data gathering

Redundancy in substation comms



Information to communicate

- Ac measurements – V, A, W, VAR
- Synchrophasors with time tags
  - S'phasor vs. message time tags
  - M vs. P filtering
  - Distribution – s'phasors optional
- Boolean status – breakers, alarms, etc.
- Boolean high speed control
- Analog control – interface to power electronic control systems
- Distribution info not necessarily thru substation

Relays as WAMPAC interfaces

- New fault protection relays on network can also serve s'phasors, binary values, control points
- Tie to WAMPAC controllers with minimum added substation equipment
  - Integrated reporting
  - Reduced maintenance
  - But…think hard when working on equipment – what are maintenance use cases?

Communications protocols

- IEC 61850-8-1 GOOSE
  - Boolean, analog, synchrophasor/time tag payload fields
  - Multicast publish/subscribe on LAN or bridge on WAN
- IEEE C37.118 synchrophasors on Ethernet
  - Similar C37.118.2 comms under development
- IEEE C37.118.1 synchrophasors in IEC 61850-90-5 wide area transport format under development
- Unsynchronized metered values, status, and control points (especially distribution info)
  - IEC 61850-8-1 server-client
  - IEC 61850-1 GOOSE
  - IEC 61850-90-2 (under development)
  - IEC 60870-5 or DNP3 on Ethernet or serial
  - Modbus over Ethernet or serial

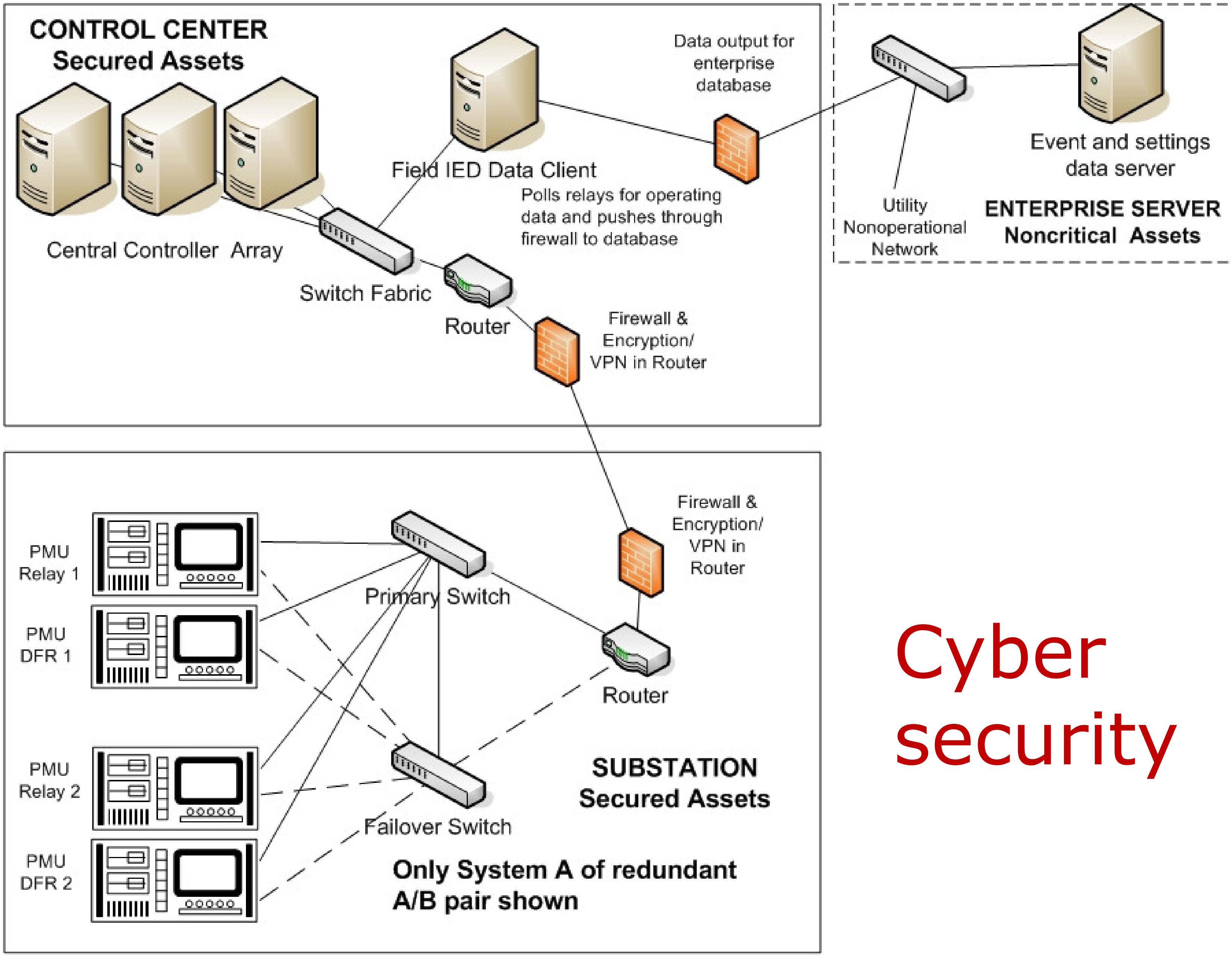
Time synchronization

- GPS satellite – dual redundant receivers and time distribution…still vulnerable!
- IEEE 1588 precision Ethernet network time protocol
  - Compatible routers and switches on the market
  - Application profile under development at IEEE PSRC

Wide area networks

- Physically diverse routing of redundant paths
- Highest unavailability component – impacts of a particular path outage?
- Data crossover at substation or control center
- Utilities and common carriers – a new opportunity
- Encrypted cyber security over distance path

Cyber security



Specifications

- Latency time budget
  - Two 50 Hz cycles for measurements – 40 ms
  - Time to produce message – 18 ms
  - Uplink time – 20 ms
  - Central processing time – 30 ms
  - Downlink time – 20 ms
  - Control output time by substation relay or IED after receipt of message – 12 ms
  - Overall WAMPAC response time –140 ms
  - Circuit breaker interrupting time – 60 ms
  - Total primary time for mitigation – 200 ms
- How to trim down to 120 ms – in chapter

Specifications

- Availability – numbers look more challenging when system does so much
  - Typical single relay - 99.999986%
  - Typical single comms link – 99.95%
  - 100 substations and redundancy – *some* link is out about 10% of the time
  - Use redundancy, condition monitoring, alarming, maintenance deployment, maintenance design

Maintenance strategy

- Can't turn off full WAMPAC for testing or repair
- Design for full condition monitoring
  - See conference paper, PACworld article, NERC Reliability Std. PRC-005-2
  - Natural testing of unmonitored I/O
- Control center programming –
  - Analytic separation
  - Staging/test facility
- Huge configuration management requirement
  - Tightly managed archive of settings & configuration
  - Use cases for deployment of changes

WAMPAC information handling

- More development work than the WAMPAC functions!
- System users – operators, P&C engineers, system planners, maintenance personnel, asset managers, regulatory compliance managers, business managers, capital planners,…
- Use cases for information analysis, presentation, storage
- WAMPAC becomes a valued tool, vs. a big extra work burden!

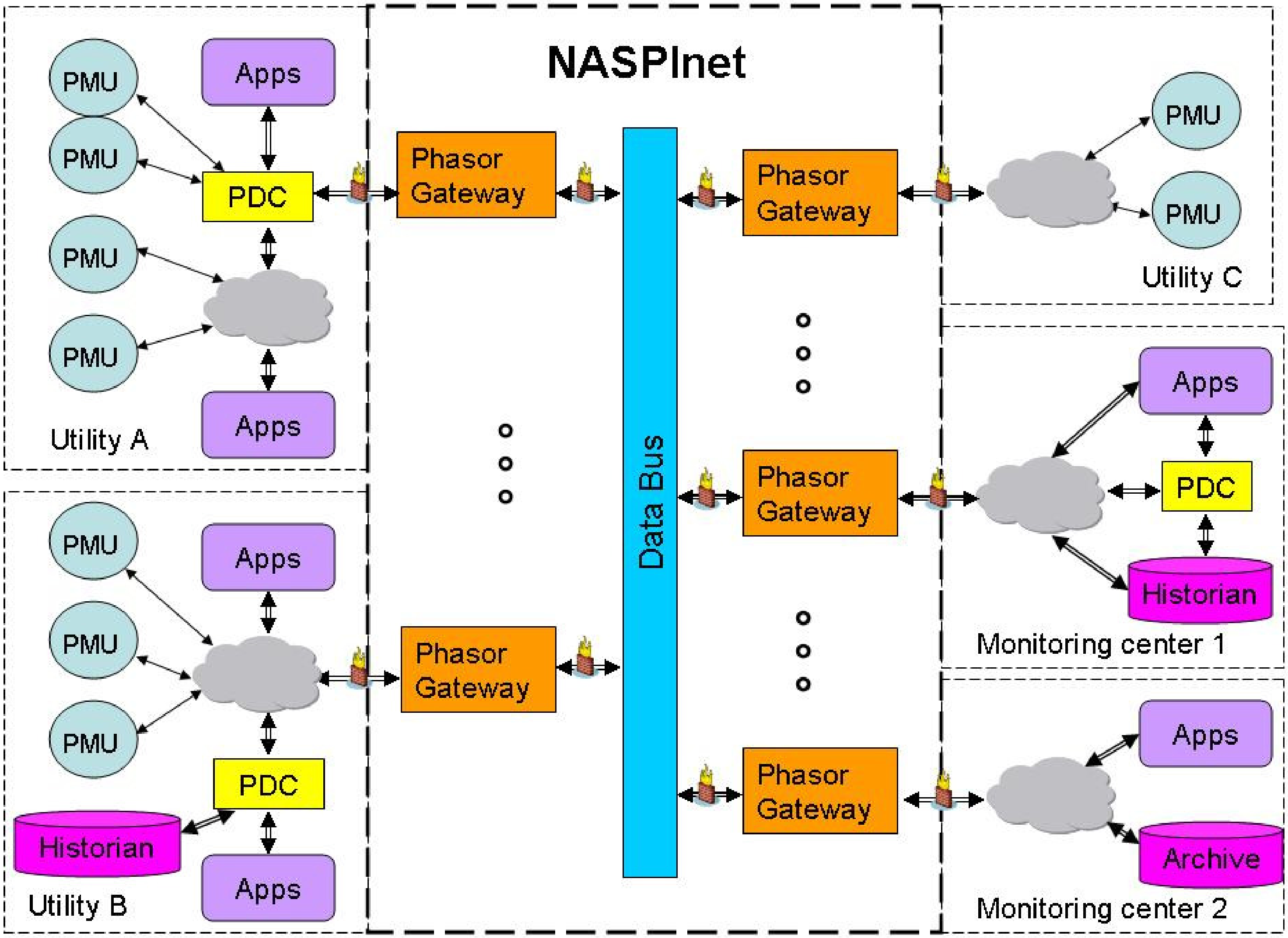
Training and testing

- Maintenance technicians don't have routine hands on experience – need a training center – learn by trial & error
- Need to test new designs, components, algorithms, configurations
- Need to demo to stakeholders and funders
- Make a duplicate demo system in an attractive open location
- Tie as dummy into live operating centers

WAMPAC application examples

- System monitoring & EMS functions
- Wide area V control & balancing
- Wide area angular or voltage instability protection
- RASs – proactive protection via planning studies
- Wide area backup protection
  - Complete backup electrical measurements
  - Kirchoff’s law – area current differential
- Central gen & DER management
- Local fault prot, local control, WAMPAC replace SCADA, EMS, backup protection, individual RAS

NASPInet – wide area access & sharing



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Conclusion - WAMPAC roadmap

- Create enterprise use cases and data presentation
- Use WAM/NASPInet data from real disturbances to validate and tune system planning and protection system models to build confidence
- Expand system dynamic modeling to include better generating plant and DER behavior.
- Expand system dynamic modeling to include secondary systems – effects of relays during faults and swings.
- Define high-speed real time protection algorithms validated from experience and accurate models
- Expand measurement infrastructure to provide full isolated redundancy

Conclusion - WAMPAC roadmap

- Expand data communications infrastructure for full isolated path redundancy, performance and availability monitoring, low latency, and cyber security
- Implement redundant precision time distribution including IEEE 1588
- Expand WAM platforms to provide computing bandwidth and redundancy for critical control functions
- Open-loop test of P&C algorithms until secure and dependable.
- Deploy development and training installations - train operators, managers, maintenance technicians, regulatory compliance personnel, etc.
- Close the control loops and enter the WAMPAC era!

Questions?