Building a Global ATM Network for Ground Systems Control

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Agenda

- *The Air Force Satellite Control Network (AFSCN)*
- Interaction between Technical Capabilities and System-Level Design
- System Engineering by Committee
- Role of Network Abstraction in System Engineering Process
- Lessons Learned

The AFSCN

- AFSCN Elements
  - 2 Operational Control Nodes (OCNs)
  - 10 Remote Ground Facilities (RGFs)
    - world-wide presence
  - Provides satellite operators control of assets and access to telemetry data
- The Range and Communications Development Contract (RCDC)
  - Operational Switch Replacement (OSR)
    - Update Communication Segment equipment
    - Provide distributed control and monitor via an IP network
    - Remove central serial switch with network-based switching
  - AFSCN Development Integration (ADI)
    - Developed to perform Communication System integration
    - Designed long-haul communications architecture
    - Supported by Aerospace, Air Force Space Command, Air Force SMC, etc.

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Key AFSCN Requirements

- Dynamic routing of traffic
  - Provide Satellite Operations Centers direct access to resources
- Eliminate untoward routing
  - Bandwidth limitations require limiting traffic flows to specific, expected paths
- Minimize Single Points of Failure
  - Diverse path routing
    - Must provide separate primary and additional paths to resources
  - Provide primary path robustness
    - Network can survive equipment failure on the primary path
  - Provide additional path robustness
    - Network can survive equipment failure on the additional path

AFSCN Constraints

- Use Asynchronous Transfer Mode (ATM) technology for long-haul communications
    - Provided by Defense Information Systems Agency (DISA)
- Network equipment selected before design completed
    - Cisco Catalyst 5500 switch/routers
        - Previously purchased for OSR project
    - Timeplex CX-1500 ATM-to-serial converters
- Bandwidth limitation on satellite paths
- Communication cost cannot increase with upgrade

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System Development Process

- Normal Development Phases
  - Define requirements
  - Request technical and cost proposals
    - Perform high-level system design
    - Choose implementation to fulfill design and requirements
  - Implementation
    - Design the system and individual components
- What happens when much of the implementation is chosen during the requirements definition?
  - Unsure how to factor cost into design process
  - Places constraints on the high-level design
  - Merges high-level design with the implementation design
    - Result: Technical constraints flow into high-level design

Details in the Design Process

- Considerations for high-level design
  - Robustness
  - Cost
  - Stability
- Considerations for implementation-level design
  - Type of service
  - Quality of Service (QoS) parameters
  - Link availability (always on vs. bandwidth on demand)
  - Routing hierarchy details
- Service Provider offerings
  - Current capabilities vs. expected upgrades
  - Difficult to anticipate future changes

Example: SVC versus PVP

- Switched Virtual Circuits (SVC) – dynamic links
  - Give up stability for robustness
    - “Wave of the future”
  - On-demand bandwidth reduces cost
  - “Cutting edge” implementation
    - ADI needed to assist DISA in defining new service offerings
    - DISA could not provide operational SVC service
- Permanent Virtual Paths (PVP) – dedicated links
  - Give up robustness for stability
    - “All eggs in one basket”
  - Always available for traffic – AFSCN requirement
    - QoS values will be constant for all circuits
    - “Industry standard” implementation

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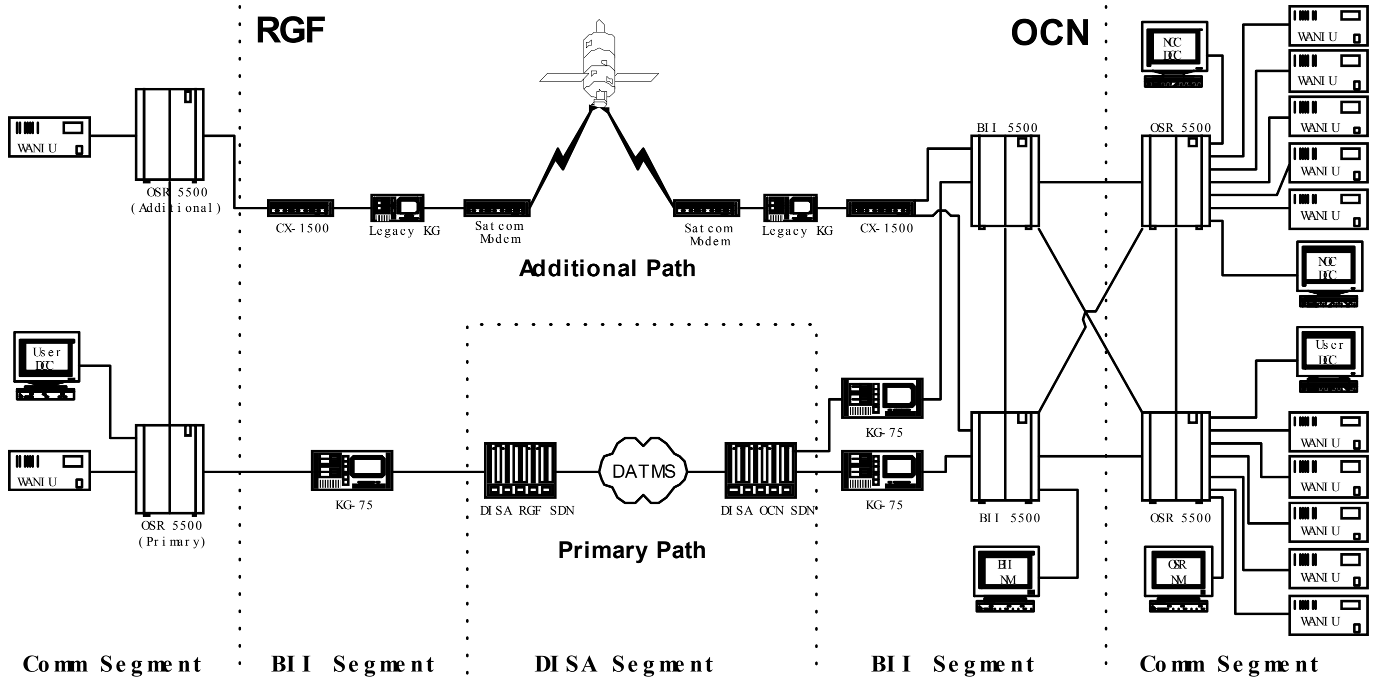
System Engineering By Committee

The AFSCN Communications System



- RCDC responsible for Comm Segment
- ADI members responsible for the rest and integrating components

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Challenges of "System Engineering by Committee"

- Multiple players means multiple priorities
  - Separate priorities cause conflict
  - Without a leader, conflicts can become deadlocks
- Access to information not always equal
  - Part of this information includes factors leading to definition of priorities
- Diversity in understanding project issues
  - Most noticeable with technical concepts

Players and Priorities

- Procurement
  - Air Force Satellite Control Network Program Office (SMC/CW)
    - GFE communications developed to support OSR product with clear interface for easy integration
  - RCDC
    - OSR provided GFE communications necessary to meet specifications
- Operations
  - Space Command Operations
    - Final system can support operational needs
  - Space Command Communications
    - Final system upgrade should be maintainable
- Service Provider
  - DISA
    - Provide service while maintaining a stable network for other users

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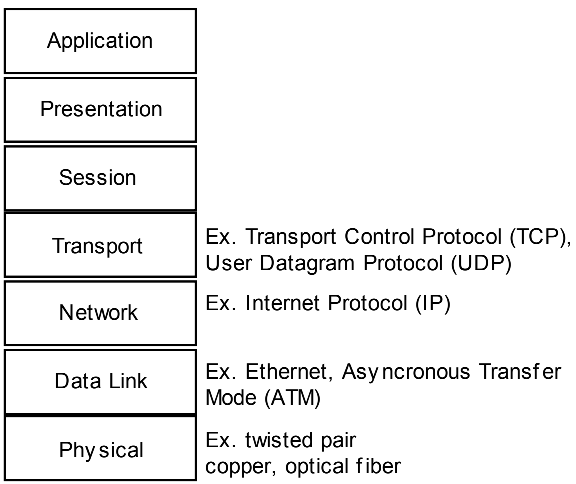
Network Abstraction

- Network abstraction inherent in modern computer network design



OSI Network Architecture

- The traditional Open System Interconnection (OSI) network architecture contains 7 layers of abstraction
  - Crucial layers for network design are usually the bottom three
  - Higher layers typically have more capabilities and “intelligence”
- Legacy communications design dealt almost entirely with the physical layer

- Understanding abstract and overlay networks is a difficult task
  - Requires significant paradigm shift from the legacy era

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Physical Layer

- Primary Path
  - Wired connection to DISA ATM fiber network for most sites
  - Serial satellite path to DISA ATM fiber network for other sites
    - Interface for AFSCN is ATM, not serial
- Additional Path
  - T1 architecture
    - A serial T1 connection between RGF and each OCN
  - "Broadcast" architecture
    - A serial connection from each OCN to given RGF
    - A broadcast satellite connection from given RGF to both OCNs

Abstract Layer 1 - ATM

- Permanent Virtual Paths (PVPs)
  - Dedicated Virtual Path Identifiers (VPIs) for each customer
- Switched Virtual Circuits (SVCs)
  - Virtual Channel Identifier (VCI) dynamically allocated upon call setup
- AFSCN architecture provisions a map of PVPs
  - Equipment tunnels individual SVCs through the PVPs
  - Uses CX-1500 device to convert ATM cells to and from serial streams
- Summary: Architecture allows for logically placing separate communication links (PVPs) on the same physical transmission medium.

Abstract Layer 2 – IP / PNNI

- Design uses Private Network to Network Interface (PNNI) protocol to propagate circuit paths
  - Hierarchical design uses logical nodes on physical switches
  - Logical nodes in charge of propagating paths to higher and lower levels
- Design uses Local Area Network Emulation (LANE)
  - Mechanism that emulates an IP network over an ATM architecture
  - Requires using SVC connections
- IP routing domain exists at all 12 sites
  - Uses Open Shortest Path First (OSPF) routing protocol
- Summary: Architecture overlays the ATM network map with an IP network map.

Conclusions

- The final architecture has several layers of abstraction inherent in its design
  - PVPs riding on links
  - SVCs tunneled through PVPs
  - Multiple layers within PNNI hierarchy
  - IP network overlays LANE ATM links
- Engineering a similar network requires architects to be able to work with abstractions
  - Must see the boundaries of each layer
  - Must see how changes in one layer affect the others
  - Abstractions are fundamental to understanding of complete architecture
  - Difficult adjustment for operators of legacy communication systems

Lessons Learned

- Tradeoffs in design always exist
  - Document decisions for when they will inevitably be revisited
- Define requirements in advance
  - Separate high-level design from implementation design
  - Decide up front what role cost will play in design
- Dedicate individuals and decisions to an Integrated Product Team (IPT) or keep the responsibility with one organization
- Beware of system's dependencies on areas beyond your control (e.g. Service Providers)
- Level of technical understanding required by operations personnel and decision makers is increasing
- Competence at abstract thinking will be a requirement for future ground system designers

Acknowledgments

The Aerospace Corporation
Carl Sunshine (Chief Engineer)
S. Michele Johnson (Systems Director)
Wayne Otsuki (ADI Lead)
Jim Swope (OSR Lead)
Dennis Kuli
Jim Miller
Alan Foonberg

ADI Development Team Members
Capt Mark Kilgore (USAF SMC/CWNE)
Kathleen Morgan (Albin Engineering)
Steve A. Nelson (Scitor Corporation)
Dylan Romano (Lockheed-Martin Missile Systems)
Jose Ramirez (Lockheed-Martin Missile Systems)
Deb White (SI International)

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