State-Based Network Management

November 12, 2004

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General Introduction to SBNM Presentation

- Relevance to Systems Engineering
- Organization of today's talk
  - Example of SBNM in failure mode: recent electricity blackout
  - Deconstruction of control systems in electricity
  - Telecommunications management practices
  - Model-based Communications Network (MCN) Framework
  - Examples
- "Telecommunications in Complex Systems Failure: The Electricity Blackout of August 14, 2003" NPS, ITCSM12

SBNM in Failure Mode:
Northern Ohio, August 14, 2003

This case study will reveal useful network management principles and practices that can be transferred across industry lines. It will also assess the analyses and causes of this particular outage.

Organization

- Motivation and Purpose
- Event Description and Background
- Event Chronology
- Systems Chronology
- Electricity Management System Issues
- Lessons Learned and next steps

Motivation and Purpose

- Argue for stateful network management for telecommunications, *inter alia*, based on example set in electric industry.
- Argue for standards-based management for electricity, *inter alia*, based on example set in telecommunications.
- Begin to organize a new paradigm for distributed realtime network management.

Event Description and Background: Recall August 14, 2003

- Largest electricity in U.S. history
  - 50 million people out of power in US, Canada
  - 61,800 MW of load lost
  - 265 power plants lost, 410 generating units
  - Millions of work hours lost
  - Over $10 billion in US economic costs
  - Began in Ohio

Regulation and Structure of the U.S. Electric Industry

- Consider: Generation, Transmission, Distribution functions
  - Deregulation, unbundling of generation
  - A/K/A retail competition, “choice”
- Regional transmission (“Transco”) operators
  - Supposed to work independently from owner
- Resulting notion of “congestion” where transmission bottlenecks impede “contract paths”

Event Chronology
Per Joint US-Canada Task Force

- Warm (not hot) day
- System Operating at 95% of peak
  - inductive/reactive characteristics due to A/C
- 12:15 Normal Degradation
- 13:31 Generator 'trips'
- 14:14 Computer failures commence
- 15:15 Local transmission failures
- 15:39 Collapse of transmission network
- 16:08 Restoration commences

Computer System Failures

- 12:15 Transco “state estimator” problems
- 14:02 Transco mis-interprets events
- 14:14 Wireco alarm system fails
- 14:20 Wireco loses consoles
- 14:41 Wireco server fails, restarts at 15:08
- 14:54 Wireco backup server fails
- 15:46 Wireco reboots servers

Determination of Causes Per Joint US-Canada Task Force

- Inadequate System Understanding
  - By Wireco, which has 3 operating subsidiaries
  - Did not model relevant conteingencies
- Inadequate Situation Awareness
  - Unaware of telemetry problems
  - Alarm system effectively offline throughout
- Vegetation Management
- Inadequate Realtime Diagnostic Tools
  - No single view of facilities and interconnections

Woods and Reason: Latent Failure Models

- Consider the latent factors that make such incidents inevitable.
  - Deregulation created dynamic systems that defy the laws of physics (i.e., Kirchoff's Law)
  - Software errors exist undetected
    - XA/21 deadly embrace – system hung, later rebooted
  - Unreasonable to blame human agent involved: operators, tree trimmers, etc.
  - Clumsy automation systems are inadequate to model the underlying phenomena

Power System Management
Energy Management Systems

- EMS encompasses System Control and Data Acquisition (SCADA) and Automatic Generation Control (AGC)
- Goal of (N-1) Security
- State model considers voltage and phase angle at transmission, generation elements
- Outcomes include: to shed load, to reject an order, or to redispatch generation
- State modeling occurs every 2 minutes, with contingency modeling performed every 30 mins.

EMS State Modeling Procedure
For Transmission System Operator

1. Import telemetry data (mostly analog)

1a. Inspect network topology

1b. Convert input data to correct units

1c. Quality check of converted data

2. Iterative estimation of remaining elements

3. Calculation of load flows

4. Reporting

Modern State Estimation
Monticelli, 2000

- Overdetermined linear systems
  - constraints based on facility limitations
  - recall goals: (1) security, (2) efficient operation
- Inevitable missing or bad data, causing some parameters to be treated as random variables for estimation
- Significant lag can occur before data is presented to model; suggests GPS timestamps of data!

Lessons Learned from EMS

- State provides description and prediction
  - Inputs include supply, demand, and facility telemetry
- System interconnections are modeled
  - Ability to control is a facet of interconnection
- Out-of-band management infrastructure
- Lacking
  - Standards-based components
  - IP-ready plug-and-play component

Telecommunications Backgrounder

- Resources are in place only to sustain peak usage, not the sum of all possible demands.
- From circuits to packets: devices store-and-forward stuff
- Typically no broadcast paradigm: traffic is directed, often filtered
- Functionality is essentially delivered through software using a layered protocol architecture. Consider TCP/IP:
  - L1: Physical, an unstructured bit service
  - L2: Data Link, reliable mechanism between 2 adjacent nodes
  - L3: Network, from links, provide forwarding (routing) on address
  - L4: Transport, ensure E2E reliability; overcome L3 weaknesses
  - L5: Application
- Strong arguments exist for L6 (content), L0 (media)

Rethinking Networking

- From thinking…
  - Only infrastructure
  - Monitor, diagnose
  - Permanent services
  - Layered architecture
  - Device independence provides reliability
  - Centrality inhibits scalability

- To thinking …
  - Include applications
  - And control
  - Switched / on-demand
  - Cross-layer design
  - Collaboration

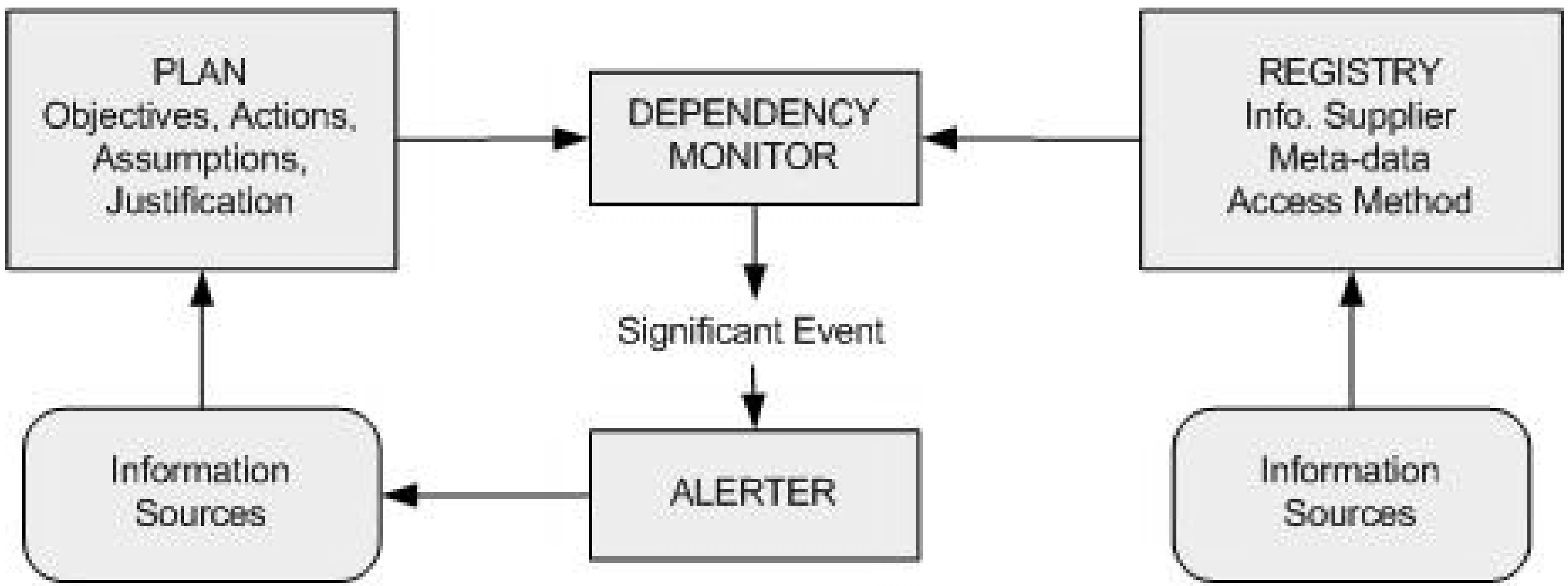
  - Add: asynch objects

Network Management Current Capabilities

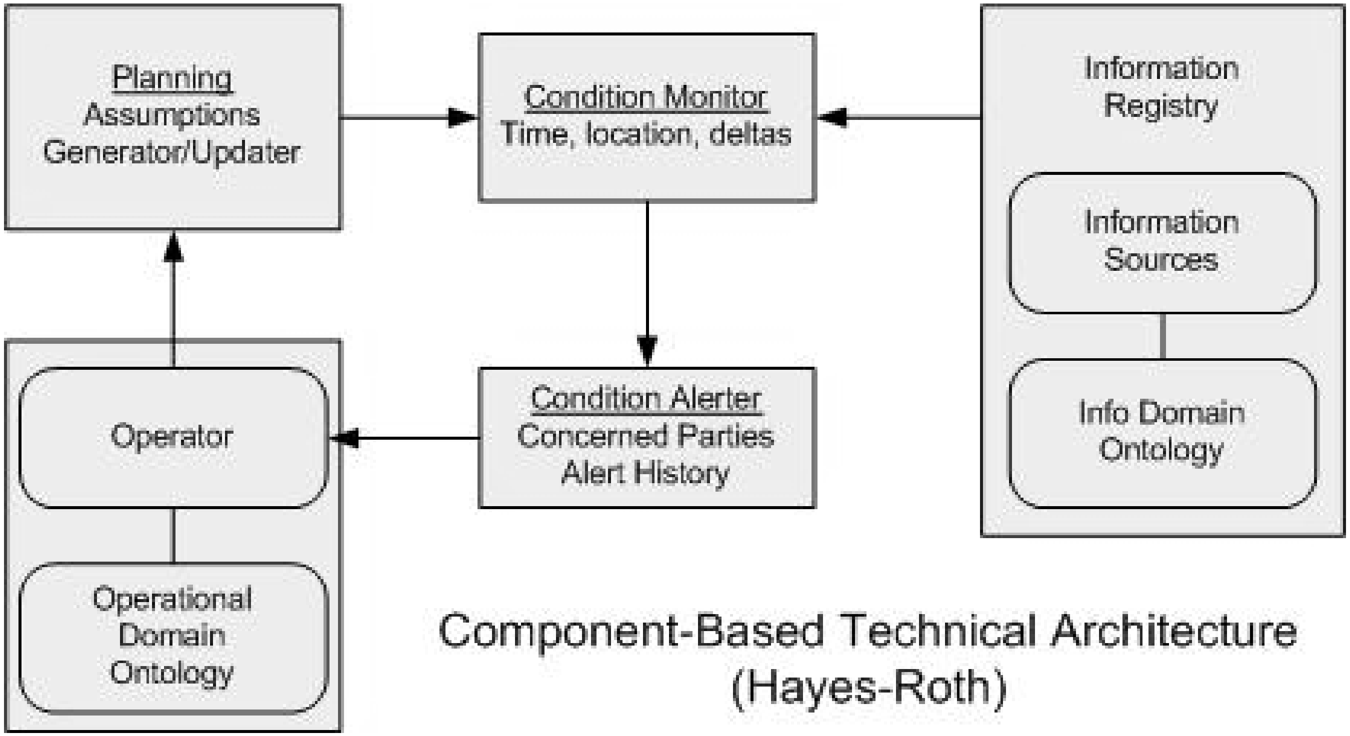
- Application software that can receive traps and poll the Management Information Base (MIB) for each device.
- Interaction contains verbs to *get* and *set* device MIBs
- Topology must be manually entered and maintained
  - limited “discovery” capability due to switched non-broadcast LAN
- Arduous task of Event Correlation (filtering redundancy)
- Strictly in-band, using unreliable protocol
- Except for carriers, WAN may not be directly visible, thus monitored indirectly through higher-layer interfaces
- State-of-the-market: integration with service dispatch
- Also may be used to monitor security events

State-Based Network Management

- Given network graphs models S=(N,Q) or S=(t, N, Q)
- SBNM is a structure for service delivery based on network device collaboration. A mechanism for allocating net resources.
- Separate “plane” from service delivery; not logically “in-band” with service delivery network
- Based on notion of time-valued information
  - “Valued Information at the Right Time” (Hayes-Roth)
  - New definition for Quality of Service (Landry, Grace, Saidi)
- Not interesting or applicable in settings with permanently provisioned resources, such as LANs.
- Not a taxonomy.



VIRT Architecture (Hayes-Roth)



Component-Based Technical Architecture
(Hayes-Roth)

Planning Component

Facet	Value
Name	***Planning Toolset***
Attribute	Key Assumptions
Attribute	Plans
Method	Plan Generator
Method	Plan Evaluator
Method	Plan Justifier
Method	Dependency Analyzer
Method	Condition Generator
Method	Plan Updater
Interface	User Interface
Interface	Machine Interface
Interconnection	Uses Operational ontology
	Generates Condition Monitors
	Receive Alerts
Quality	Generate good plans
	Easy to accept VIRT data
	Quick VIRT response time

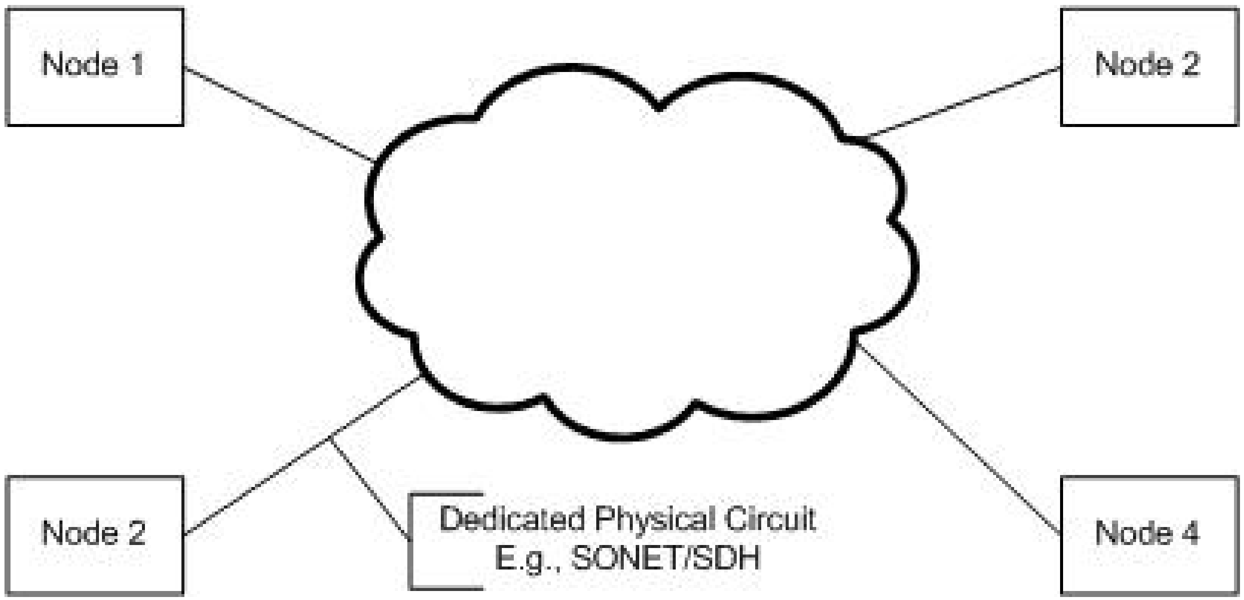
Condition Monitor Component

Facet	Value
Name	***Condition Monitor***
Attribute	Condition (t,N,QoS)
Attribute	Significant deltas
Attribute	Agenda for updates
Method	Update Cond (t, N, QoS)
Method	Get update
Method	Accept update
Method	ID significant deltas
Method	Set agenda
Interface	Machine I/F
Interconnection	Access info registry
	Access info sources
	Use domain translator
	Signal Condition alerter
Quality	Effective at detecting event
	Efficient with costly resources

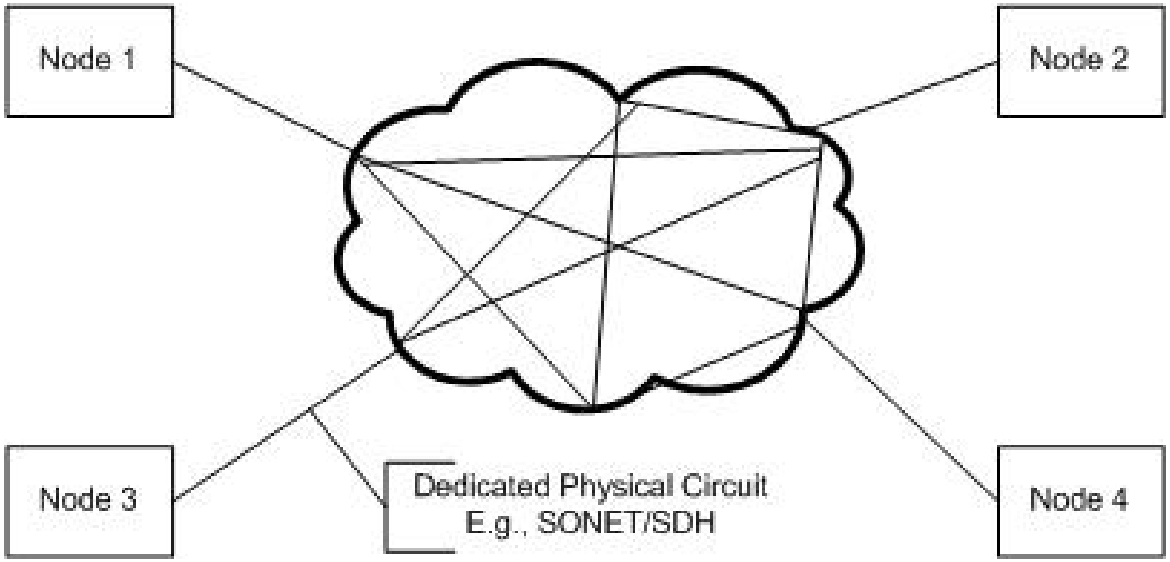
Information Registry Component

Facet	Value
Name	***Information Registry***
Attribute	Information Sources
Attribute	Information Domain Ontologies
Method	Update Info Sources
Method	Update Domain Ontologies
Interface	Machine I/F
Interconnection	Condition Monitor Reads
	Domain Translator Reads
Quality	Easy to update, administer
	Supports diverse, evolving sources

User Perspective on Network



Operator Perspective on Network



Example 1
Video Teleconference on Demand

- Setting: OEM, supplier(s) discuss part issue; network provider under contract to provide connection as needed
- Planner: provision SVCs between endpoints; one node contains an Multipoint Conference Unit (MCU)
- Registry: status (t, N, QoS) carries performance, outages
- Condition Monitor: polls registry for updates
- Close loop, via operational ontology, to alert Planner
- Event: given a minimum latency topology, deal with a link outage that requires longer paths or a different MCU
- Outcome: Planner to obtain sufficient resources to comply with contract, even if it needs to pre-empt others

Example 2
Inbound Channelized Voice Calls

- Setting: inbound calls are direct to open offices from east to west across time zones as offices close; assume this is a network (not PBX) function; consider ATM - or VoIP?
- Information Registry: outage list (SONET), device (mux, ATM switch) status, capacity/loading
- Event: transportation or protection failure
- Outcome: Notify planner (software) of outage and allow it to execute an alternative within its list

Example 3
Mobile Ad-Hoc Network (MANET) <u>Device</u>

- Setting: Battlefield Packet Voice Talkgroup Comms; every device provides store-and-forward relay
- Planner: maintain path and geo-location information for each station in talkgroup as each stations moves
- Registry: for neighbors, maintains infrastructure status, geo-location, and talkgroup information; for self-device, maintains condition & communication routing information
- Condition Monitor: Polls registry for significant events
- Event: Low Battery
- Outcome: Planner directs device into no-relay mode (perhaps simplex) and informs operator

Example 4
Electric Generation & Transmission

- Already fulfills the basic control objective of SBNM
  - Regionalism is appropriate scope
- Multiple wholesale providers and (distribution) customers
- Competitive business setting at all levels
- Interoperability of dispatch will require standards
  - Recommend; component objects
- Interconnection of all wholesale entities is a requirement
- SBNM may require rejection of orders

Conclusions and Final Remarks

- A gap exists between theory and practice. One author contends that the study of network management has not advanced in *ten years*.
- Cost of deploying intelligence in devices is not prohibitive
  - Bandwidth is available to support necessary messaging
- Next steps
  - Complete one application domain in depth
  - Seek some useful reference graphic
  - Seek metric or evaluation tool

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