Architecture for Cognitive Networking within NASA’s Future Space Communications Infrastructure

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Agenda

• Discuss cognitive and possible roles in future SCaN
• Discuss architecture concepts
  – What might cognitive look like?
  – Definitely more than just the radios!
• Describe Cognitive Agent prototype software
  – Cognitive networking framework on the SCaN Testbed
• What does future work look like?
SCaN Future Architecture

• Moving away from discrete networks
  – Space Network, Near Earth Network, Deep Space Network, …

• Moving toward unified architecture
  – Seamless service provision, service interfaces, and scheduling for all network elements
  – Cross-layer services: raw signals, bitstreams, link-layer frames, packets, UDP, delay-tolerant networking, …

• Future solar system internet (SSI) as described by CCSDS
  – International, government, and commercial users
    • Should all use networks responsibly …

• Goals for cognitive
  – Reduce user burden
  – Mitigate operational risks due to growing complexity
  – Open-loop communication and navigation services
    • Reduce need for direct operator intervention
Goals: NASA Intelligent Routing (NITRO) Effort

1. **Reduce operator burden**
   
   Enhance performance on operational efficiency metrics ...

2. **Improve operator efficiency**
   
   Support scale-up in complexity, diversity, and volume / capacity ...
   
   ... without a corresponding scale-up in human resource allocations

3. **Facilitate autonomous operations**
   
   Enable operations where no human can support communications infrastructure (e.g. Mars)
Iterative Development

**Static Network Configurations**
- Early DTN Experiments
  - Manually configured node parameters, routing plans, etc.

**Dynamic Network Configurations**
- Reactive Control Plane Protocols (e.g. Link State Routing)
  - Typical Internet Routing (OSPF, etc)
    - Protocol detects and reacts to link and network changes, contacts may be ad-hoc
- Time-Triggered Configurations
  - Contact Graph Routing
    - Protocol conveys expected future events, but other node configuration parameters may still be manually managed

**Predictive Network Configurations**
- Proactive Control Plane
  - Temporospatial SDN
    - Centralized intelligence finds optimal network-wide configurations and distributes to nodes
- Cognitive Control Plane
  - Goal for NITRO
    - Distributed cognitive agents autonomously learn network conditions, correlations, and behaviors

**Operator Burden**

**System Intelligence**
Toward Cognitive System Engineering

• Not really One True Cognitive to rule them all
  – Instead, things are situationally appropriate
    • Huge number of different AI and ML techniques
      – Neural networks, genetic programming, SVM, and more!
    • Different techniques make sense in different situations
    • Need to blend autonomy and automation …
      – … in ways that make sense for the mission
  – Many different techniques to achieve cognitive behaviors …
    • Cognitive offload – perform computation elsewhere
    • Autonomic computing / networking – “self-management”
    • Information-centric networking – emphasize “what”, not “where”
  – … optimized across many different “domains”
    • “big brain vs. little brain”
Prototype Cognitive Agent

- Prototyping intelligent routing software and protocol
  - Built to support present and future flight / ground systems
    - Current on-orbit testing via SCaN Testbed...
- Empirically determines link characteristics ...
  - ... and makes routing decisions based on goals
    - “minimize latency”, “maximize reliability”, etc.
- Also collects data that can be used for future work ...
  - In order to learn, we need data from which to learn ...
- ... and offers a way to swap cognitive engines
  - Less of a focus on immediate intelligence in *this* agent
  - More of a focus on a good API and an extensible framework
    - Make future experiments easier ...
Cogent – Construction

Legacy Applications

TCP/UDP

IP

COTS

CCSDS

Cognitive Applications

Cogent

Cogent

Upper Layer Interfaces

Probes

Cognitive Engine

Routing Information

Scheduler

Lower Layer Interfaces

Feedback
Technology Gaps and Future Work

• Cross-layer signaling
  – Standardization is an important aspect of this …

• Algorithm development
  – More intelligent approaches to autonomy and management

• Computational offload
  – Incremental upgrade of static hardware resources

• Debugging / management of intelligent systems
  – “You did WHAT?! What were you THINKING?!”

• Self-knowledge
  – “Generally, I’m not very good at …”

• Self-design
  – “Wouldn’t it be nice if I could fly?”
Wrapping Things Up

• Thanks for listening!

• Speaker: Gilbert Clark – gilbert.j.clark@nasa.gov
  – Feel free to contact with questions, concerns, etc.

• Questions? Comments? Concerns? Criticisms?