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

Presented By: Gilbert Clark / MTI Systems

Authors
Gilbert Clark and Wesley M. Eddy/MTI Systems
Sandra K. Johnson/NASA Glenn Research Center
James Barnes/MTI Systems
David Brooks/VPL
Presenter Biography
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

<table>
<thead>
<tr>
<th>Static Network Configurations</th>
<th>Dynamic Network Configurations</th>
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</thead>
<tbody>
<tr>
<td>Reactive Control Plane Protocols (e.g. Link State Routing)</td>
<td>Predictive Network Configurations</td>
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<tr>
<td>Early DTN Experiments</td>
<td>Time-Triggered Configurations</td>
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<tr>
<td>Typical Internet Routing (OSPF, etc)</td>
<td>Proactive Control Plane</td>
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<td>Manually configured node parameters, routing plans, etc.</td>
<td>Cognitive Control Plane</td>
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<td>Protocol detects and reacts to link and network changes, contacts may be ad-hoc</td>
<td>Temporospatial SDN</td>
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<tr>
<td>Protocol conveys expected future events, but other node configuration parameters may still be manually managed</td>
<td>Goal for NITRO</td>
</tr>
<tr>
<td>Centralized intelligence finds optimal network-wide configurations and distributes to nodes</td>
<td>Distributed cognitive agents autonomously learn network conditions, correlations, and behaviors</td>
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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”
Cognitive Scope
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
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?