IAB Technical Discussion: Satellite Networking

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We SHOULD mix cultures, experiences, and expertise.

A space network is a combination of space expertise and internet expertise.

**IETF**
- Areas
  - Real-Time Apps
  - Internetworking
  - Ops/Mgmt
  - Routing
  - Security
  - Transport

**CCSDS**
- Areas
  - Systems Engineering
  - Missions Ops/Mgmt
  - Cross-Support
  - Spacecraft Onboard
  - Space Link
  - Space Internetworking

**Space Networking**
- Produce base standards
- Customize IETF documents for space systems
What should space networks look like?
A space-agency-centric view

- **Store and Forward Data Exchange**
  - *Do not* assume a path exists all at once.
  - *Do not* assume endpoints remember things for you.
  - *Do not* retransmit from the source. Inchworm through the network.
  - *Do* store data for milliseconds… or days.
  - *Do* carry all data and metadata in the same message.

- **End-to-end Security**
  - *Do not* rely solely on physical layer security.
  - *Do* secure different parts of a packet separately.
  - *Do* optimize for security at rest.

- **Autonomy as Network Management**
  - *Do not* assume an operator in the loop.
  - *Do* incorporate autonomy and automation. Operator “on” the loop.
  - *Do* push information proactively into the network.
  - *Do* be compatible with terrestrial management approaches.

- **Routing**
  - *Do* adjust to time-variant topologies.
What is useful today?
Terrestrial best practices are not incompatible with space-agency-centric views

• What’s useful on the Internet today?
  - Content delivery networks (caching)
  - Data subscriptions (push mechanisms)
  - Autonomic computing (rules/automation)
  - Stateless data (RESTful interfaces)

• We do not have infinite access to bandwidth.
  - High priority data delays low-priority data.
  - Chatty protocols are clogging links.
  - Untrusted infrastructure may as well not exist.

• Assuming infinite bandwidth leads to problems.
  - Lots of state information at endpoints.
  - Lots of bandwidth used for “real time updates”
  - Dropping low-priority data clogs the network…
    ▪ Re-transmitted again to be dropped again.
What kind of features do we want?

“Challenged” includes predictably disrupted, randomly degraded, and intentionally contested.

- You can send data without knowing if the destination is connected or on-line.
- Re-transmissions don’t have to start over from the beginning.
- You can “bundle” payloads and annotative data together to avoid synchronization problems later.
- Endpoints do not need to remember sessions or special states.
- Familiar features! Similar to text messaging and e-mail.
- But as a standard networking protocol – every application gets these benefits.

No more point solutions.

Think through our technical debt.
Use Case 1: Local Resource Preservation

Exemplar: A power-constrained wireless sensor network

- **Scheduled Node Transmissions**
  - Radios powered as a function of time.
  - Different nodes on at different times.

- **Assumptions**
  - Power expenditures known.
  - Power accumulation (solar) predictable.
  - Resource (radio) management same.

- **Dynamic Topology**
  - Connectivity changes over time.
  - There might never be a single end-to-end path.
  - Link up/down:
    - Predictable/Schedulable.
    - Communicable.

Assume a minimum local power to turn on radio.

Figure 1: Node Power Over Time

Figure 2: Topology over Time
### Use Case 2: Adapting to External Conditions

**Assumptions and Possible TVR Benefits**

<table>
<thead>
<tr>
<th>Assumptions</th>
<th>Possible TVR Benefits</th>
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<tbody>
<tr>
<td><strong>Measureability.</strong></td>
<td></td>
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<td>- External conditions can be associated with node functions.</td>
<td><strong>Link Filtering.</strong></td>
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<tr>
<td><strong>Predictability/Schedulability</strong></td>
<td>Links filtered based on cost - minimize use of high-cost links unless needed by type of traffic (e.g. high priority).</td>
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<tr>
<td>- External conditions known in advance.</td>
<td><strong>Burst Planning.</strong></td>
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<td>- More than just “the current condition at the moment”.</td>
<td>- If fewer transmissions save costs, nodes might accumulate data volume before transmission.</td>
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<td><strong>Persistence.</strong></td>
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<td>- External condition changes are infrequent enough that behavior can be adjusted in response to their changing.</td>
<td><strong>Environmental Measurement.</strong></td>
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<tr>
<td><strong>Magnitude.</strong></td>
<td></td>
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<tr>
<td>- Savings justify the efforts required to achieve them.</td>
<td>- Environmental conditions may greatly affect throughput vs goodput (such as clouds on an optical link or long distance RF transmission in a storm). Costs can be used to address this.</td>
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<td></td>
<td><strong>Data Delivery</strong></td>
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- Data delivery less impacted by external conditions.
Use Case 3: Mobile Devices – with Predictable Connectivity

Exemplar: Networked LEO Constellation

• LEO spacecraft links are short lived
  - Passes of several minutes each.
  - Pass planning happens at ground terminals.
  - Need to understand what node is over what terminal when.

• Assumptions
  - Paths are predictable: motion and pointing can be understood in advance.
  - Environmental knowledge is predictable: The environment being transmitted to and through can be well understood.

• Dynamic Topology
  - Physical topology changes rapidly.
    • Internal network not so much (inter-satellite links)
    • Exit points (ground stations) very much.
  - Satellite handoffs need to be planned (even in close advance).