A Variable Coded Modulation (VCM) Protocol for CCSDS

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Current state of VCM in CCSDS

- VCM is a built-in feature of:
- VCM is not feature of
- Status of adaptive coded modulation (ACM):
  - None of the three standards above specify an ACM protocol (although the term “ACM” is used in the Blue Books)
  - This is because these standards relate to downlink only. As such, they do not specify a protocol for estimating signal quality or feeding channel-state information back to the spacecraft for the purpose of selecting a new transmission mode.
  - The SCCC and DVB-S2 standards are compatible with ACM: the transmission modes may be modified and the slicer must be able to apply the change without losing Transfer Frames
Objectives for a CCSDS VCM Protocol

- Our previous presentations have showed that VCM with CCSDS turbo and AR4JA/C2 LDPC codes can approximately double returned data volume in typical application scenarios.
- This motivates the development of a CCSDS recommended VCM protocol for the turbo and AR4JA/C2 LDPC codes

Desired properties of a VCM protocol:
- It should properly handle use of the turbo and AR4JA/C2 LDPC codes
- Ideally, it should encompass or be very similar to the existing protocols used for SCCC and BCH-LDPC codes, i.e., an encompassing protocol
- It should have small overhead, particularly when the coded modulation mode is not changing often
- Switching quickly between modes should be possible, without losing Transfer Frames
- It should be compatible with future development of ACM protocols
- It should be compatible with future development of new channel codes, e.g., not be dependent on particular codes, or even lengths
SCCC VCM protocol:

- Transfer Frames + ASMs are sliced, asynchronously, into input codeblocks
- These are encoded
- 16 encoded blocks make one Physical Layer Frame
- A Physical Layer header is prepended, comprising
  - 256-bit Frame Marker (sync)
  - 64-bit Frame Descriptor (VCM mode)
- Pilot symbols, if desired, are inserted

A minor modification makes the VCM protocol applicable to other codes:

- Allow Frame Descriptors to refer to user-selectable channel codes and modulations, not just SCCC.
- Allow codewords to be lengths other than 8100 symbols
VCM “Frame descriptor” for SCCC specifies which of 27 ACM formats is used:

<table>
<thead>
<tr>
<th>Bit Number</th>
<th>Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>$b_1$ - $b_5$</td>
<td>ACM Formats (Decimal values 1 to 27 are used with bit $b_1$ being the most significant bit)</td>
</tr>
<tr>
<td>$b_6$</td>
<td>Distributed Pilot On (=1) / Off (=0)</td>
</tr>
<tr>
<td>$b_7$</td>
<td>Reserved (set to 0)</td>
</tr>
</tbody>
</table>

The bits $b_1$ – $b_5$ could easily be allowed to refer to any codes, including the CCSDS turbo and AR4JA/C2 LDPC codes.
JPL has conducted tests of this modified protocol, and verified that it works well:

- The Frame Marker (FM) can be reliably detected
  - Even when the blocklength is allowed to vary, as we suggest
  - Even down to the low SNRs that rate 1/6 turbo codes use (see figure at right)
- The Frame Descriptor (FD) can be reliably detected or deduced
  - For high code rates, the FD can be detected with sufficiently low error probability
  - For lower code rates, FD can be deduced from a designed unique separation between FMs, in the different modes.
  - (This means the FD doesn’t really need to be transmitted.)

U of Alaska at Fairbanks has confirmed the operation of the protocol in hardware tests, using a software-defined radio.
Recommended Steps

• NASA will write a formal specification (Orange Book) of a VCM protocol
  • This will not impact existing SCCC and DVB-S2 standards, but will leverage them
• NASA requests that this activity be approved for a standards track, i.e., Red Book.