Priority Code Scheme for Flexible Scheduling in High Throughput Satellites
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◆Objective: Propose a scheme that is capable to respond users demands by dynamically scheduling frequency resources into specific satellite coverage areas.

◆The priority code scheme (PCS) is based on increasing capacity in coverage areas with high demand of resources, and at the same time, minimizing the amount of resources dedicated to low loaded regions.

◆The goal is to reduce the under and overload resource events inside specific footprints to take full advantage of frequency resources.
High Throughput Satellites (HTS)

High Throughput Satellites reach large number of users, providing high data rates at low cost.

Their implementation involves to deploy a large number of small sized beams.

Beam Radius \( B_R = 100 \text{ Km} \)
Priority Code Scheme

Input
- Monitoring parameters
  - Finding out under/overload events

Output
- Adjustment of the frequency resource allocation
  - Assignment of priority codes

- Efficiency ratio
- Efficiency indicator
- Efficiency threshold

Beam - Priority Codes: 1, 2, 3, and 4

System Capacity = 600 MHz

P 200 MHz
G 200 MHz
B 200 MHz

Overload Bandwidth
Underload Bandwidth
Non-used resources
Missing resources

η<sub>t</sub> = Efficiency threshold
η<sub>r</sub> = Efficiency ratio
η<sub>i</sub> = Efficiency indicator

Beam<sub>1</sub>
Beam<sub>2</sub>

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Priority Code Scheme Process

\[ \eta_t = \text{Efficiency threshold} \]

Overload \( 0.75 - 0.85 \)
Underload

\[ \eta_r = 0.1, 0.2, 0.3, ..., 0.8, ..., 0.95, 0.99, 1 \]

\( \eta_r = \text{Utilization/Capacity} = \text{Efficiency ratio} \)

\( \eta_t = \text{Efficiency indicator} \)

Overload Bandwidth

Non-used resources \( \eta_r = 0.1 \)

Underload Bandwidth

Missing resources \( \eta_r = 0.99 \)

\( \eta_r = 0.8 \)

\( \eta_r = 0.99 \)

\( \eta_i = \text{Efficiency indicator} \)

\( \eta_t = \text{Efficiency threshold} = 0.75 - 0.85 \)

Table I: Priority Code

<table>
<thead>
<tr>
<th>Demand</th>
<th>Priority Code</th>
<th>Efficiency [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>4</td>
<td>60</td>
</tr>
<tr>
<td>Medium</td>
<td>3</td>
<td>25</td>
</tr>
<tr>
<td>Low</td>
<td>2</td>
<td>10</td>
</tr>
<tr>
<td>Little</td>
<td>1</td>
<td>5</td>
</tr>
</tbody>
</table>

PCS Target

Identify inconvenient scenarios

To monitor periodically three parameters

Verify Priority Code

Bandwidth allocation adjustment

Marginal to perform bandwidth allocation more efficiently.
PCS Frequency Reuse Plan

System Capacity = 600 MHz

Group₁, Group₄, Group₇, Group₂, Group₅, Group₈, Group₁₀ Group₃, Group₆, Group₉

200 MHz

Group 1

200 MHz

Group 4

200 MHz

Group 7

Group 2, Group 5

Group 8

Group 10

Group 3, Group 6, Group 9

P

Beam 1

Beam 2

Beam 3

Beam 4

Beam 5

Beam 6

Beam 7

G

Inter-group guard band 500 kHz

Beam 5

Intra-group guard band 500 kHz

28 MHz

Inter-group guard band 500 kHz

200 MHz

R_{inter} = 1/3, R_{intra} = 1/7

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Intra-Group Interference

ψ = Inter-band interference that occurs inside each group.
BG = Number of Beam Groups.
EIRP = Equivalent Isotropically Related Power.
L = Free Space Loss.
Gr = Antenna Gain of the satellite.
Gsh = Shadowing Components of the satellite.
k = Number of beams inside each group.

\[ I_{\text{intra-group}} = \sum_{BG=1}^{10} \psi_{BG} \]

\[ \psi = \sum_{k=1}^{7} EIRP_k G_{r,k} L_k G_{sh,k} \]
Inter-Group Interference

\[ Y = \sum_{k=1}^{7} \sum_{q=1}^{2} EIRP_{(k,q)} G_r(k,q) L_{(k,q)} G_{sh}(k,q) \]

\[ Y = \sum_{k=1}^{7} \sum_{m=1}^{4} EIRP_{(k,m)} G_r(k,m) L_{(k,m)} G_{sh}(k,m) \]

\[ I_{\text{inter-group}} = \sum_{BG=1}^{10} (Y_{BG} + \Omega_{BG}) \]

\[ \text{BG} = \text{Number of Beam Groups.} \]

\[ \text{EIRP} = \text{Equivalent Isotropically Related Power.} \]

\[ L = \text{Free Space Loss.} \]

\[ G_r = \text{Antenna Gain of the satellite.} \]

\[ G_{sh} = \text{Shadowing Components of the satellite.} \]

\[ k = \text{Number of beams inside each group.} \]

\[ m = \text{Number of beam groups using adjacent subsets of frequencies.} \]

\[ q = \text{Number of beam groups using the same subset of frequencies.} \]
The Fixed bandwidth allocation does not follow the network’s bandwidth demand variations. The PCS does.

\[
C = \text{Maximum Channel Bandwidth.}\n\]

\[
BW = \text{Bandwidth.}\n\]

\[
S/(N+I) = \text{Signal to Noise Radio plus Interference.}\n\]

\[I = \text{Interference}\n\]

\[
T_{\text{Syst}} = \text{System Noise Temperature.}\n\]

\[
\lambda = \text{Wavelength}\n\]

\[
G_{\text{RX}} = \text{Receiver Gain.}\n\]

\[
G_{\text{TX}} = \text{Transmitter Gain.}\n\]

\[
P_{\text{TWT A}} = \text{Payload on the space aircraft.}\n\]

\[
K_B = \text{Boltzmann’s constant.}\n\]

\[
d = \text{Distance between tx and rx.}\n\]

\[
C = BW \log_2 \left[ 1 + \left( \frac{S}{N+1} \right) \right] \]

\[
\left( \frac{S}{N+1} \right) = \frac{P_{\text{TWT A}} G_{\text{TX}} G_{\text{RX}}}{\left( \frac{4 \pi d}{\lambda} \right)^2 K_B T_{\text{Syst}} BW L} \]
PCS Interference Performance

Number of beam groups

Interference (dBm)

- Intra Group Interference (Reuse Factor = 1/7)
- Inter Group Interference (Reuse Factor = 1/3)
- Total Interference
The PCS succeeded in dynamically allocating bandwidth resources, satisfying the unstable patterns that follow the user’s demands.

The concurrency time might adopt different behaviors. For instance, if there are many bandwidth adjustments, the concurrency time is short. If there are few bandwidth adjustments, the concurrency time is long.

The docility of the concurrency time proves that the PCS algorithm is flexible and, in consequence, the PCS responds to dynamic bandwidth demands.

Conclusions