Energy-Cognizant Scheduling of Store-and-Forward Communications with Multiple Priority Levels in Nanosatellite Systems

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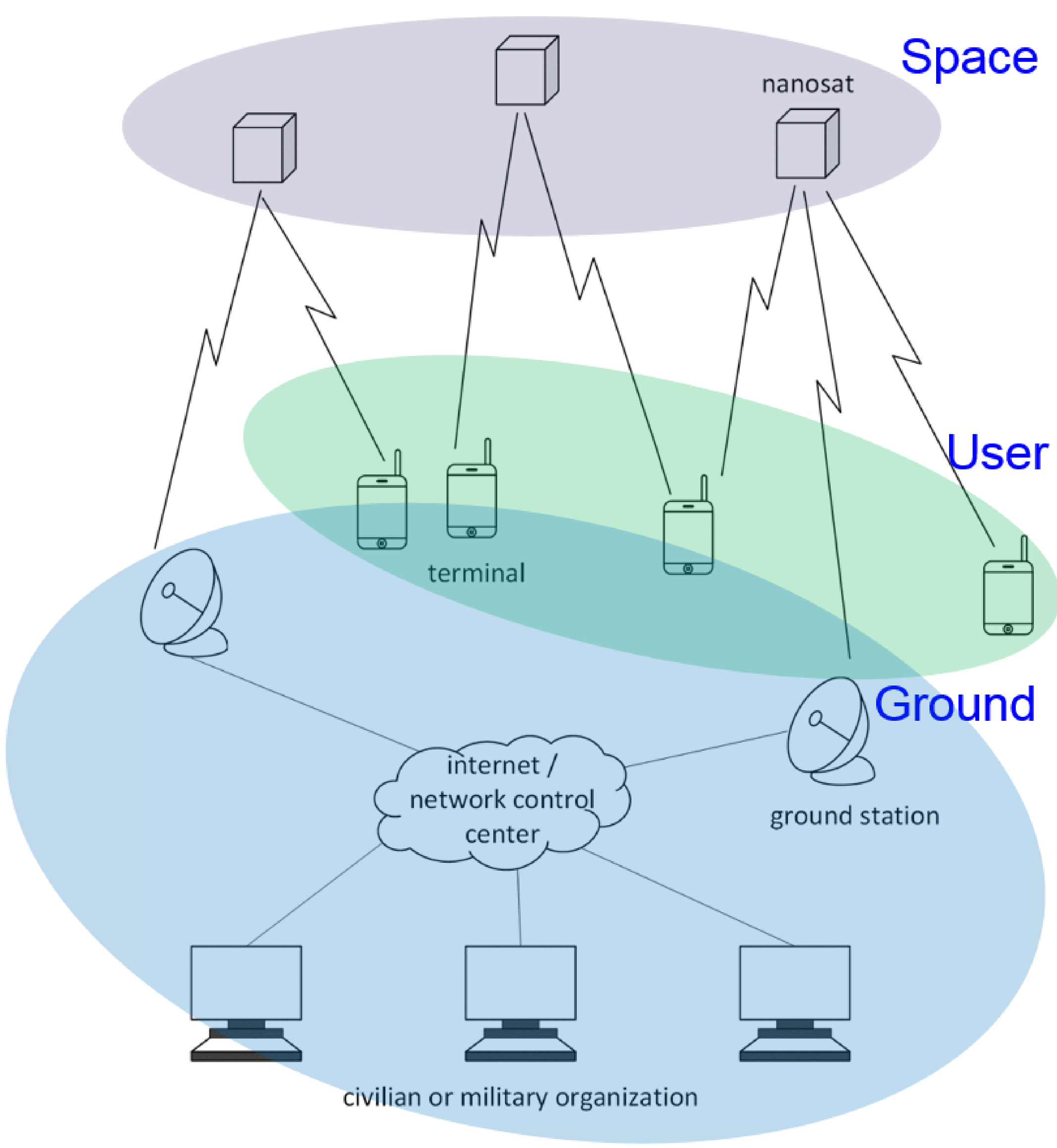
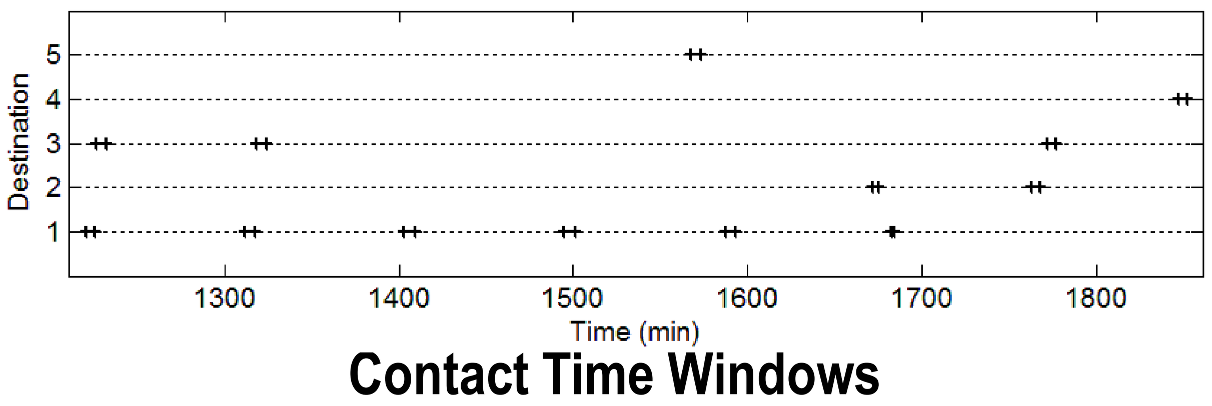
GOAL

To provide network connectivity in hard-to-reach areas using a nanosatellite constellation

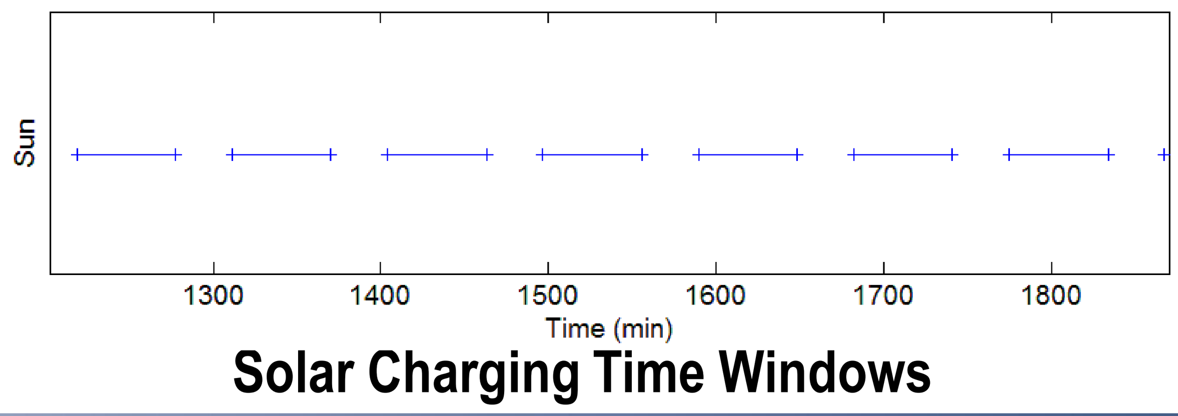


PROBLEM STATEMENT

How would nanosatellites schedule their message delivery effectively and efficiently considering nanosatellite limitations in terms of size, power onboard data storage, energy capacity and contact time windows?"



Contact Time Windows

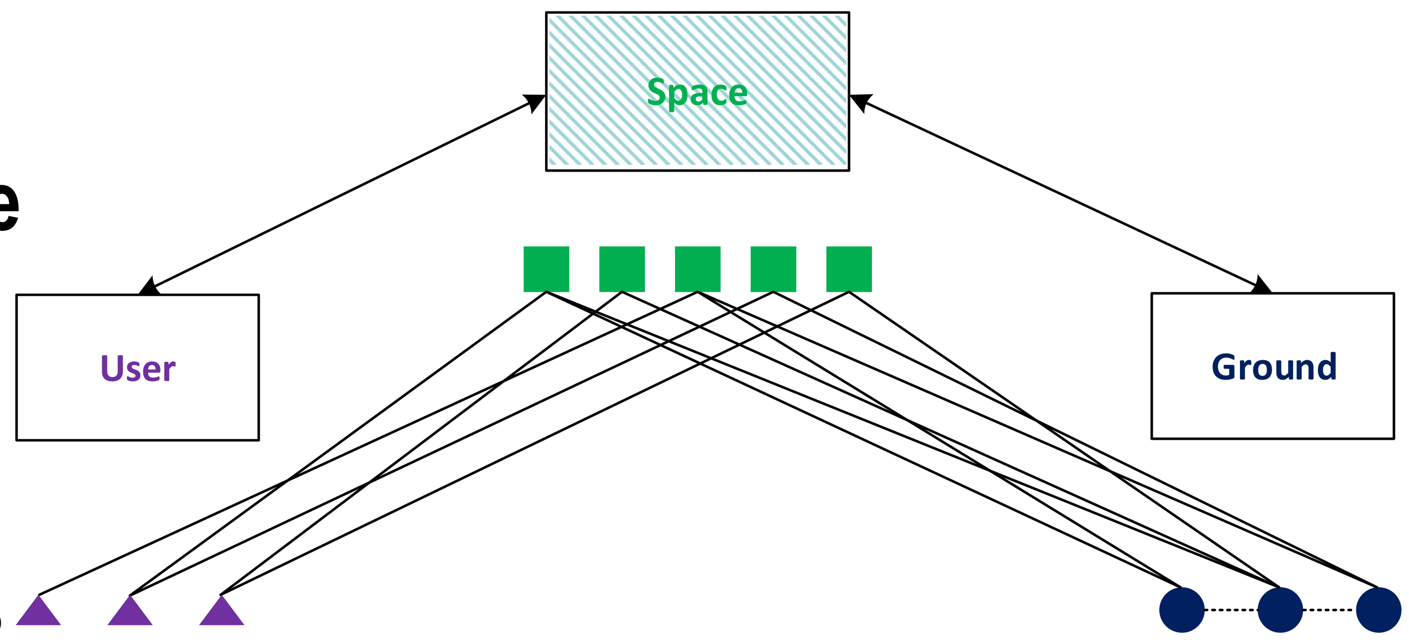


Solar Charging Time Windows

OPTIMIZATION MODELS

Nanosat Scheduling Decision Making for Single-hop Architecture

- Optimization model (P1) is a binary linear program that minimizes priority weighted delivery completion time
- Optimization model (P2) is a standard linear program with a very special structure that minimizes priority weighted mean busy times
- Optimization model (P2) has an equivalent minimum cost network flow representation, and thus the integer optimal solution is guaranteed with integer input parameters



(P2) Minimum cost network flow model

min $\sum_{j=1}^{J} w_j C_j$

subject to

$C_j \geq \tau_{k+1} u_{jk}$ for $j = 1, \dots, J, k = 0, \dots, K-1$

$\sum_{j=1}^{J} u_{jk} \leq 1$ for $k = 0, \dots, K-1$

$\sum_{k=0}^{K-1} u_{jk} = s_j$, for $j = 1, \dots, J$

$e_{k+1} = e_k + \delta_k - \sum_{j=1}^{J} u_{jk} - h_k$ for $k = 0, \dots, K-1$ and e_0 is given

$e_{min} \leq e_k \leq e_{max}$ for $k = 0, \dots, K$

$h_k \geq 0$ for $k = 0, \dots, K-1$

$C_j \geq 0$ for $j = 0, \dots, J$

$u_{jk} = \{0,1\}$ for $j = 1, \dots, J, k = 0, \dots, K-1$

(P1) Weighted completion time model

min $\sum_{j=1}^{J} \sum_{k=0}^{K-1} \frac{w_j}{s_j} \left(\tau_k + \frac{1}{2}\right) u_{jk}$

subject to

$\sum_{j=1}^{J} u_{jk} \leq 1$ for $k = 0, \dots, K-1$

$\sum_{k=0}^{K-1} u_{jk} = s_j$ for $j = 1, \dots, J$

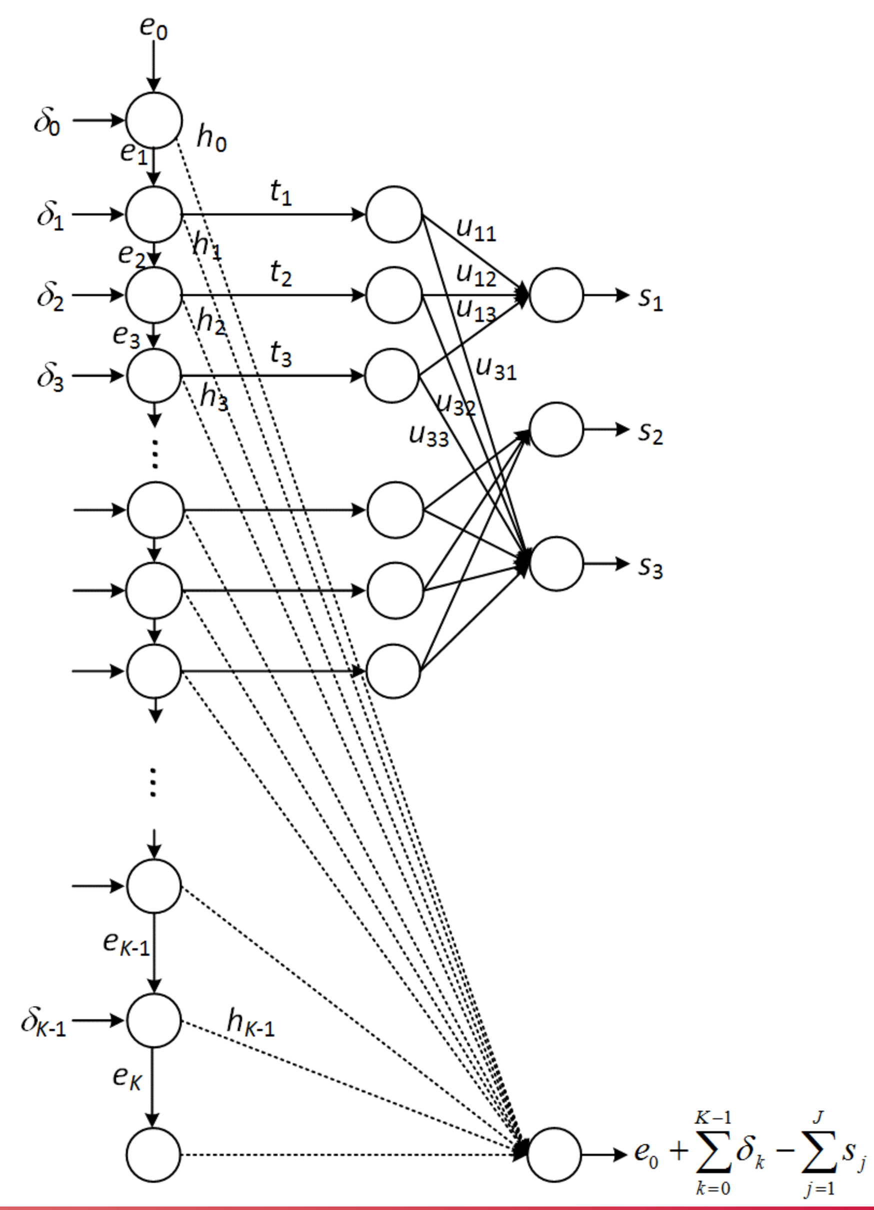
$e_{k+1} = e_k + \delta_k - \sum_{j=1}^{J} u_{jk} - h_k$ for $k = 0, \dots, K-1$ and e_0 is given

$e_{min} \leq e_k \leq e_{max}$ for $k = 0, \dots, K$

$h_k \geq 0$, for $k = 0, \dots, K$

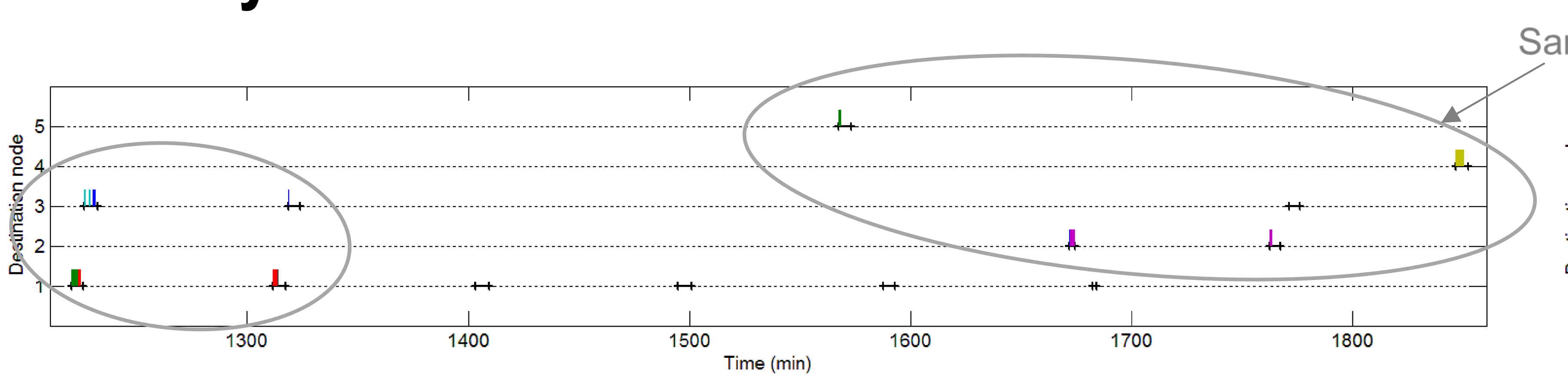
$0 \leq u_{jk} \leq 1$ for $j = 1, \dots, J, k = 0, \dots, K-1$

(P2) Weighted mean busy time model

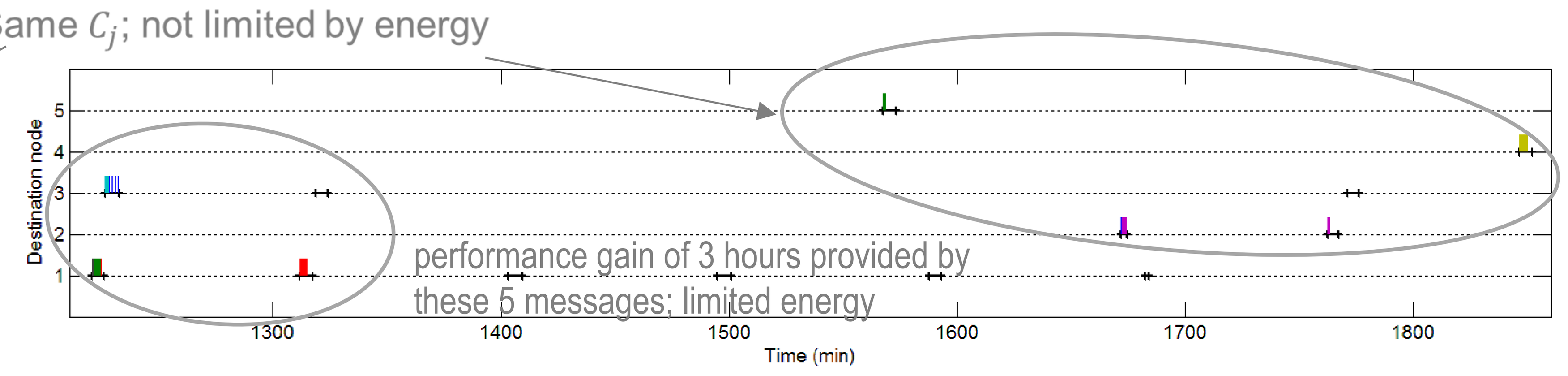


NUMERICAL RESULTS

Weighted mean busy time strategy (P2) outperforms highest priority first strategy by 3 hours in total delivery time



Highest priority first strategy



Weighted mean busy time strategy (P2)

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