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Gestion des ressources de communication pour satellites dans une fédération de constellations d'observation de la Terre

Journées Francophones de Programmation par Contraintes

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Earth Observation mission

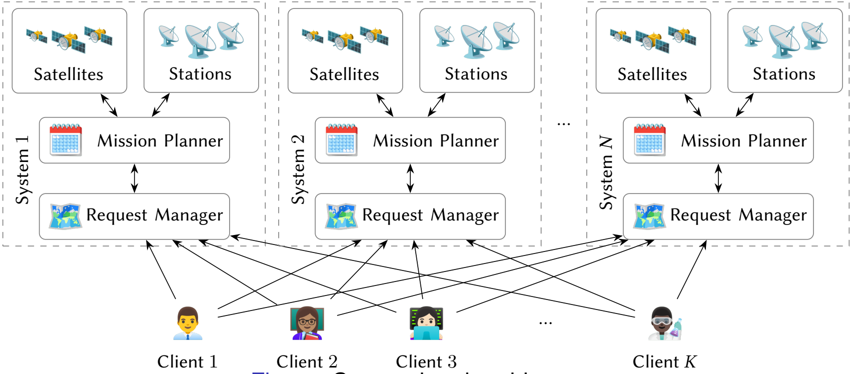

Figure: Conventional architecture

GSaaS

Third-party communication stations adopting the Ground Station as a Service (GSaaS) model [1], such as KSAT (https://www.ksat.no/ground-network-services/) and AWS (https://aws.amazon.com/ground-station/)

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Project objective

By using collaboration between missions and the GSaaS'es, increase the available data transfer per day and observations quality.

DOMINO-E European project

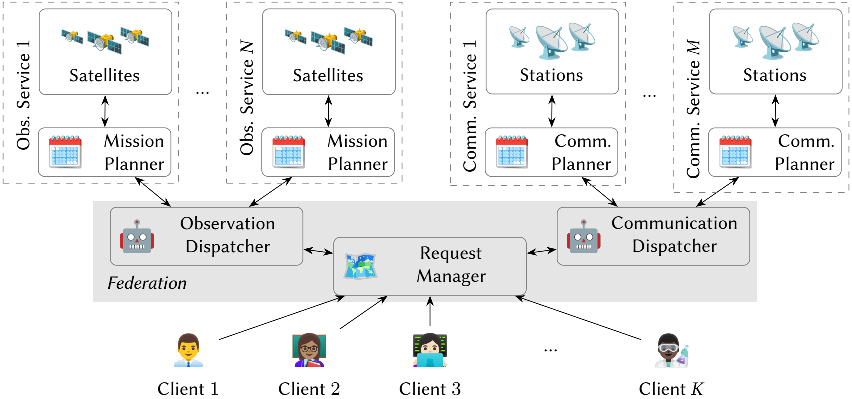

Figure: Multi mission federation [2]

Communication contact

Possible communication for satellite i when entering the visibility mask of a station:

- $s_{i,l}$ its site on ground and
- $[\underline{u}_{i,l}, \overline{u}_{i,l}]$ its time window, of duration $d_{i,l}$.

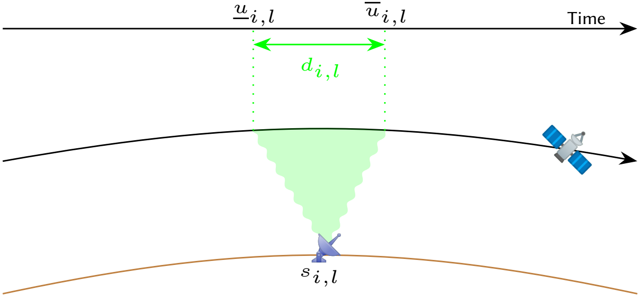

Figure: Communication contact

Communication need

Global Need

- a communication duration $D_{i,k}$,
- a time window $[\underline{t}_{i,k}, \overline{t}_{i,k}]$,
- a radio communication band: S or X, and
- a site list $\mathcal{S}_{i,k}$.

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Localized need

- an observation area,
- maximum delay

Fulfillment

Quantity of effective communication time allocated to a need k during a contact:

- needs on different band do not interfere with each other
- global need fulfillment by contact is $d_{i,k,l} = d_{i,l}$
- localized need fulfillment $d_{i,k,l}$ depends on the overlap with the specialized constraint

Fulfillment

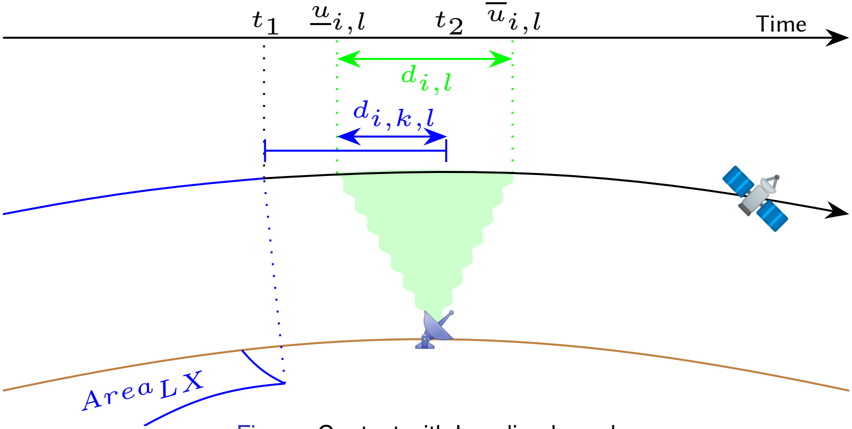


Figure: Contact with Localized need

Allocation

Boolean $x_{i,l}$ for contact l of satellite i.
Find an assignment to x for each contact which respects the constraints.

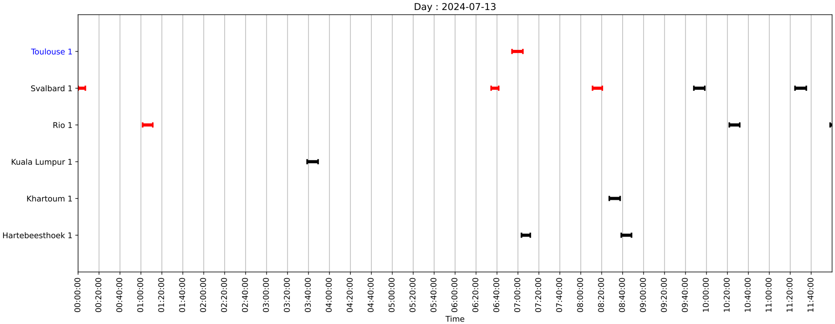


Figure: Allocation example

Objective: Jamming (Secure)

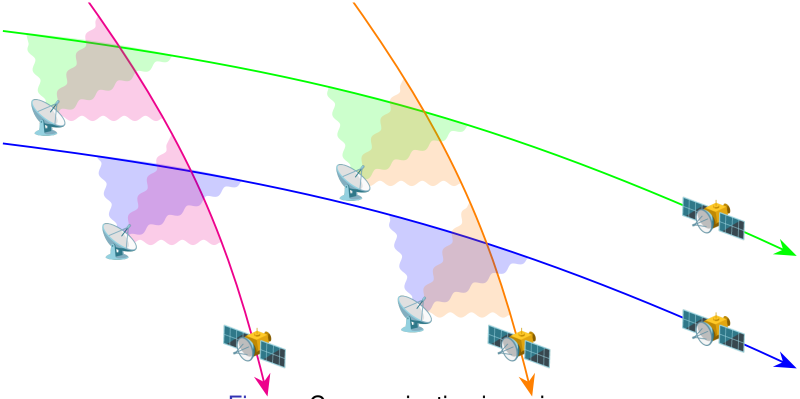


Figure: Communication jamming

Objective: Cost (Mini)

- Pay per Use (PU): cost per minute c_s^t
- Pay per Pass (PP): fixed cost for the contact c_s^0
- Pay per Pass with Commitment (PPC): fixed cost c_s^0 for contacts after a threshold Y_s

$$C = \sum_{s \in PU} \sum_{\substack{l=1 \\ |s=cm(i,l)}}^{L_i} c_s^t d_{i,l} x_{i,l} + \sum_{s \in PP} \sum_{\substack{l=1 \\ |s=cm(i,l)}}^{L_i} c_s^0 x_{i,l} + \sum_{s \in PPC} c_s^0 \max(0, \sum_{i=1}^{N} \sum_{\substack{l=1 \\ |s=cm(i,l)}}^{L_i} x_{i,l} - Y_s)$$

Simulation

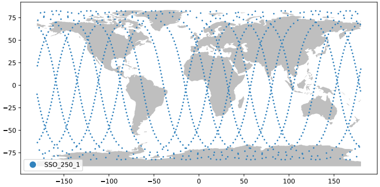
Data:

- satellite constellations,
- constellation and satellite needs requirements,
- GSaaS localizations and bands,
- GSaaS cost models

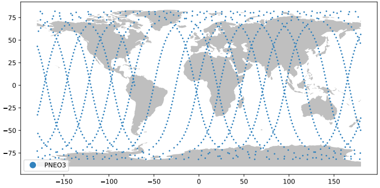
Objective: every day, find a communication plan for the federation for the next 10 days, during 60 days

Satellites

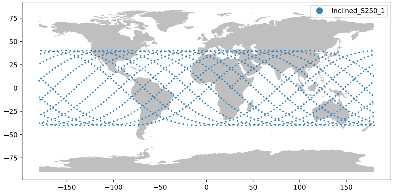
SSO_250_1



PNE03



Inclined_S250_1



- **SSO**: 4 S250 satellites on the same SSO orbit in quadrant phases
- **Inclined**: 2 pairs of S250 in phase opposition
- **PNEO**: 2 S950 satellites on the same SSO orbit in phase opposition

Day 1 satellite communication requirements

constellation/satellite	band	duration (min)
PNEO_S950	S	5
PNEO_S950	X	50
SSO_S250	S	5
SSO_S250	X	70
SSO_S250_1	X	60
Inclined_S250	S	5
Inclined_S250	X	50
Inclined_S250_1	X	50

Table: Initial routine needs per period

Need evolution

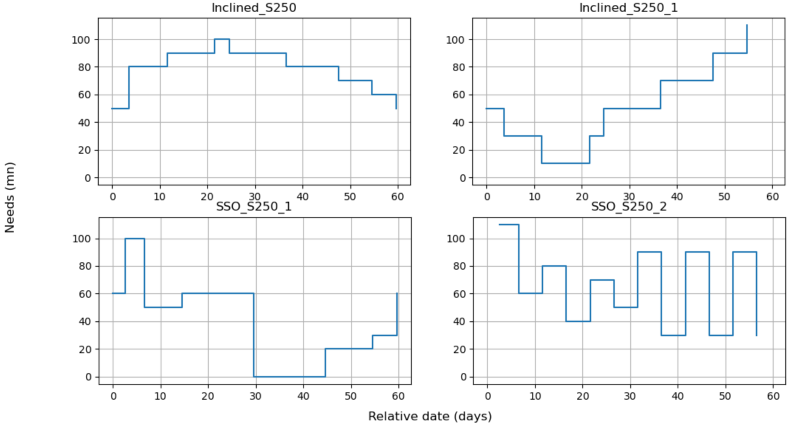


Figure: Evolution of needs in X band

Stations

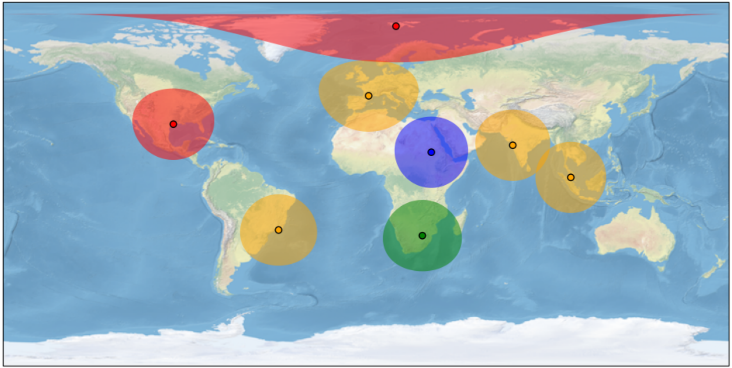


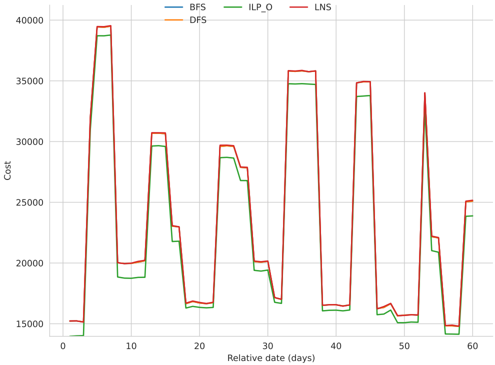
Figure: Stations and their respective visibility circles at 500km altitude: blue is Owned, green is Preferred, yellow is Normal, red is Expensive.

Cost models

Station	Type	Cost
Owned	PP	0
Preferred	PPC w. 6	50
Normal	PP	200
Expensive	PU	400

Table: Different levels of service for each provider

Cost comparison for the 60 days scenario



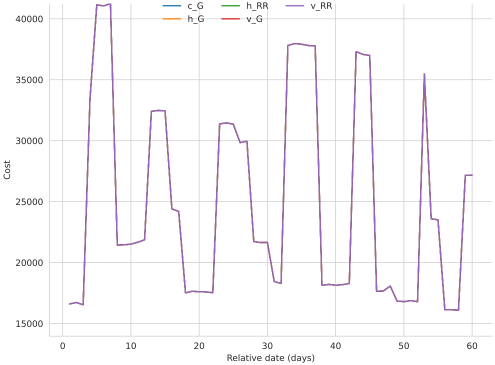


Figure: Solution cost all along the successive scenarios for all the solvers for MINI strategy

Cost comparison for the 60 days scenario

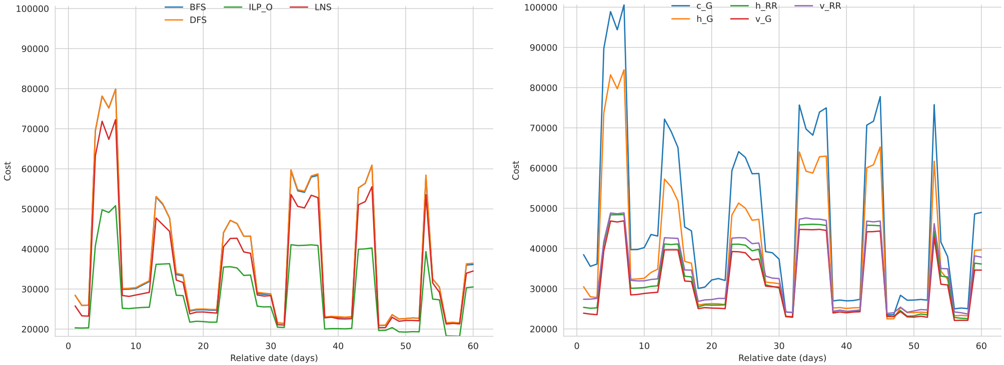


Figure: Solution cost all along the successive scenarios for all the solvers for SECURE strategy

Jamming comparison for the 60 days scenario

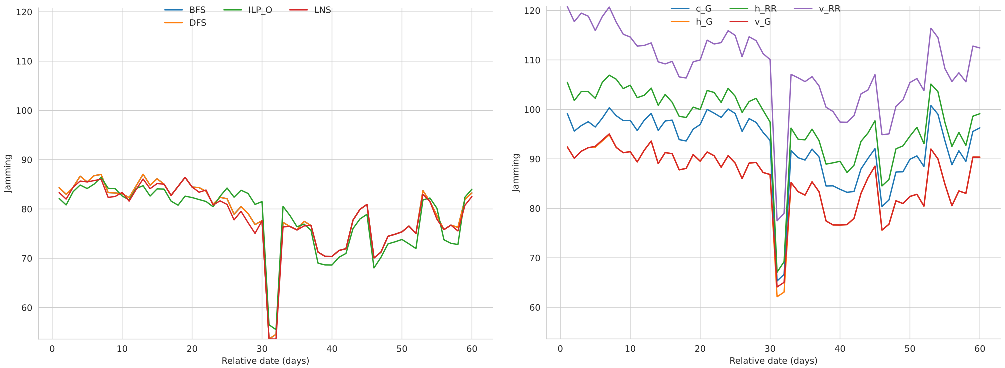


Figure: Solution Jamming all along the successive scenarios for all the solvers for MINI strategy

Jamming comparison for the 60 days scenario

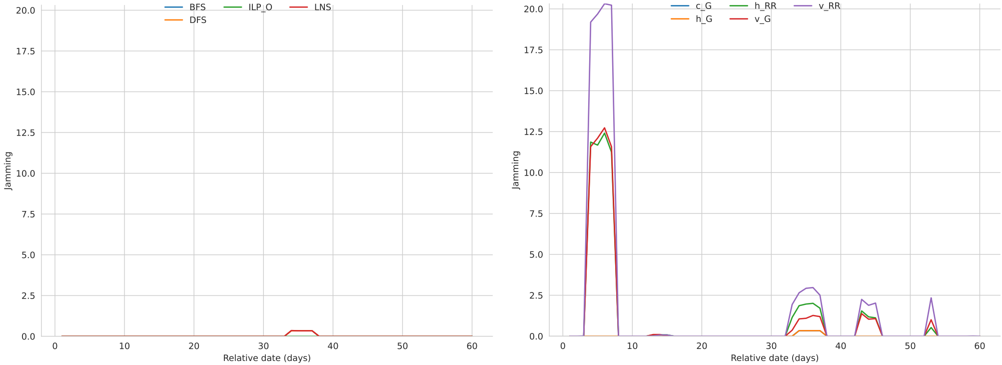


Figure: Solution cost all along the successive scenarios for all the solvers for SECURE strategy

Conclusion and perspectives

Summary

- formalization of communication needs and available cost models for the federation
- comparison of standard heuristics
- performent MILO formulation

Perspectives

- Model the uncertainty of acceptance from GSaaS
- Closed loop simulation
- Correlation with the estimated charge of the station w.r.t near satellites

Thank you for your attention !

Any questions ?

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References

[1] E. Carcaillon and B. Bancquart,
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[2] J.-L. Farges, F. S. Perotto, C. Pralet, G. Picard, C. de Lussy, J. Guerra, P. Pavero and F. Planchou,
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