DEPLOYING JOINT BEAM HOPPING AND PRECODING IN MULTIBEAM SATELLITE NETWORKS

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Abstract

- Beam Hopping to increase satellite flexibility and better fit the irregular traffic demand.
- Precoding optimizes per beam power allocation considering traffic demands weights to manage interference.

System Decription and BH scheme

Assumptions

N: number of satellite feeds
K_a: number of active beams at the time instant t_i
K_p: number of non active beams t_i

At each time instant t_i single or multiple users terminal can be served in each active beam.

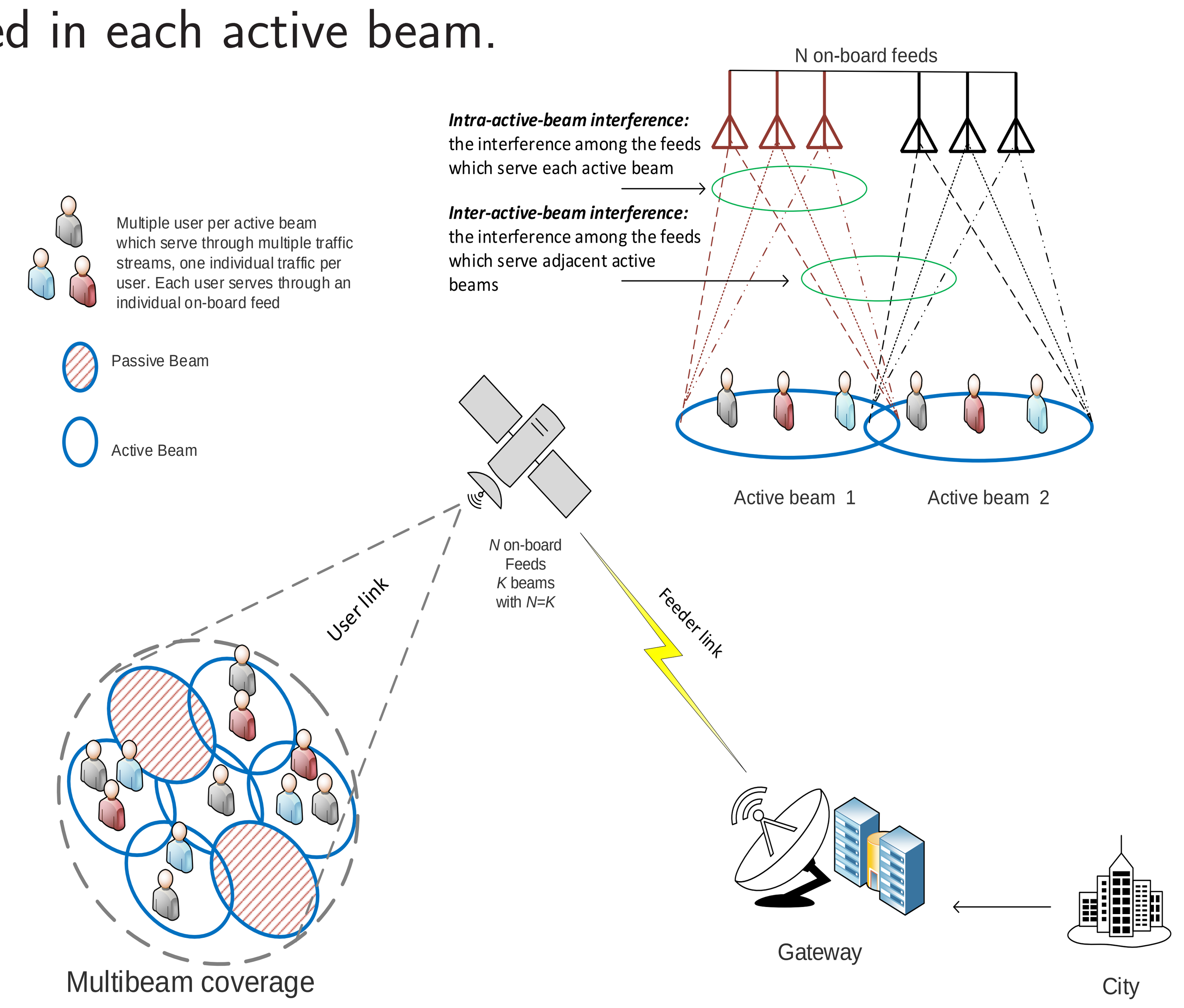
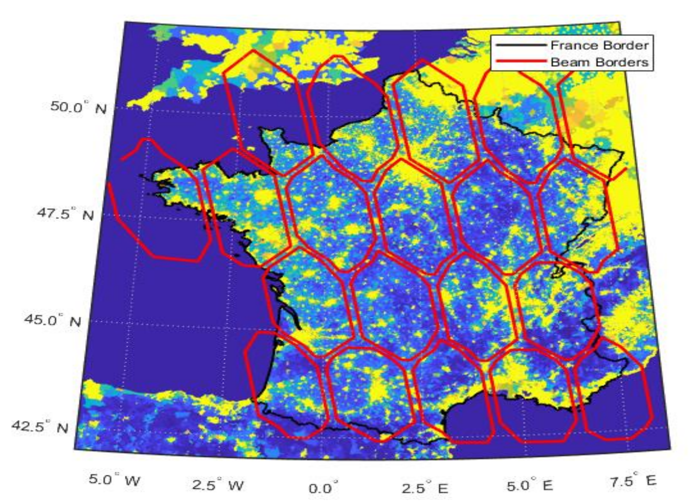
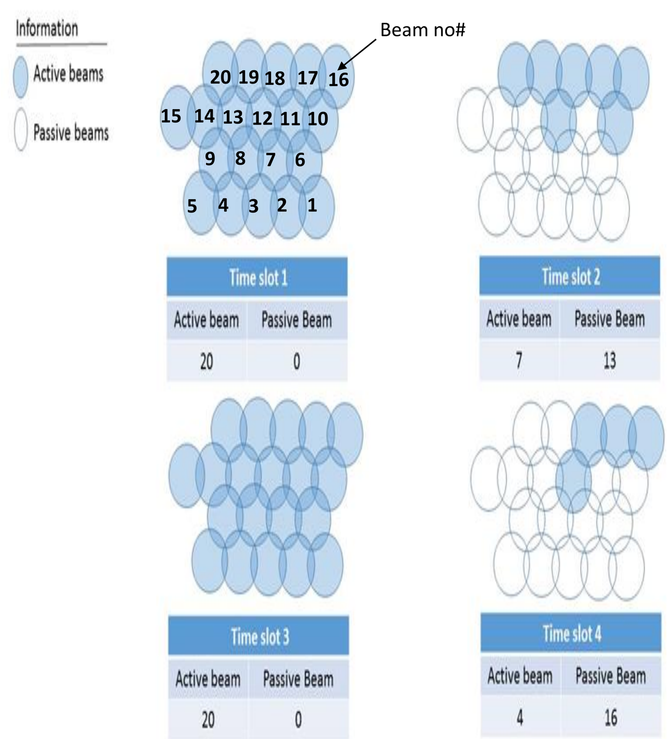


Figure 1. Multibeam Satellite System with active and passive beam





Beam no.	Population [x106]	Weight (%)	Beam no.	Population [x106]	Weight (%)
1	2.0453	1.6813	11	2.3725	1.9502
2	3.6783	3.0236	12	12.9218	10.6219
3	2.1449	1.7631	13	3.8562	3.1698
4	2.6049	2.1413	14	3.9900	3.2799
5	2.9393	2.4162	15	1.3115	1.0781
6	3.6647	3.0125	16	16.2514	13.3588
7	4.5352	3.7280	17	11.7312	9.6432
8	1.8685	1.5359	18	20.0535	16.4842
9	3.6200	2.9757	19	8.4937	6.9819
10	6.5513	5.3852	20	7.0186	5.7694

Figure 2. Population Data over France and Active Beams time slots

ZF Precoding Design

Let us assume perfect CSI.

Notation

- $\mathbf{y}(t) = \mathbf{H}(t)\mathbf{x}(t) + \mathbf{n}(t)$: Received Signal
- $\mathbf{H}(t) = \mathbf{D}(t)\mathbf{G}(t)$: Channel Matrix
- $\mathbf{x}(t) = \mathbf{W}(t)\mathbf{u}(t)$: transmitted Signal
- $\mathbf{H}^{-} \triangleq \mathbf{H}^{\dagger}(t) + \mathbf{R}^{\perp}(t)\mathbf{Q}(t)$: Generalized Inverse

The ZF design of $W(t)$ for the i-th user is equivalent to

$$\mathbf{H}(t)\mathbf{W}(t) = \text{diag}(\sqrt{\mathbf{SINR}(t)}) \qquad i = 1, \ldots, M,$$

where $\sqrt{\mathbf{SINR}(t)}$ is the vector of the SINR of the users.

Problem Formulation

$$\max_{\mathbf{SINR}(t)\geq 0, \mathbf{W}(t)} \quad f(\mathbf{SINR}(t))$$
$$s.t. \quad \mathbf{H}(t)\mathbf{W}(t) = \text{diag}\sqrt{\mathbf{SINR}(t)}$$
$$[\mathbf{W}(t)\mathbf{W}^H(t)]_{k,k} \leq \frac{P}{N} + \Delta p_k(t) \qquad k = 1, \ldots, N$$

Heuristic solution to calculate $\Delta p_k(t)$.

Calculate $\Delta p_k(t)$

$$\Delta p_k(t) = \frac{\left[2^{\left(\frac{R_{umet,k}T}{\tau_k B}\right)}(\text{SINR}_k(t)+1)\right] - 1}{\text{SINR}_k(t)},$$

with $\tau_k \triangleq \frac{R_{req,k}/\nu_k}{\sum_{n=0}^{N_{TWTA}-1}(R_{req,n}/\nu_n)} T$, such that $R_{umet,k}$ is the Unmet capacity through k-th feed. B is the band served by each TWTA amplifier and T is the total number of time slots that active beams serve.

Applying a fairness criterion we can deal with the complexity of the problem so having:

Solution for $W(t)$

$$\mathbf{W}(t) = \sqrt{s_f(t)}(\mathbf{H}^{\dagger}(t) + \mathbf{R}^{\perp}(t)\mathbf{Q}(t))$$

Simulation Results

Parameters

Link	Title	Description
Forward link parameters	Satellite height	35786 km (GEO)
	Earth radius	6378.137 Km
	Numer Of Satellites	1
	Feed radiation pattern	ESA [13]
	Number of feeds N	22
	Number of beams K	20
	Total bandwidth	500 MHz
	Roll-off factor	0.25
	Coverage area	France
	clear sky gain	17.68 G/T
	Satellite antenna gain	57 dBi
User link	Frequency	20×10^9Hz
	user antenna gain	41.7 dBi

Nº of Configuration	Number of total active and passive beams								Average offered capacity considering DVB-S2x [Gb/s]	Average unused system capacity [Gb/s]	Average unmet capacity demand [Gb/s]
	Time slot 1		Time slot 2		Time slot 3		Time slot 4				
	Act.	Pas.	Act.	Pas.	Act.	Pas.	Act.	Pas.			
4 frequency reuse	20	0	20	0	20	0	20	0	14.46	3.29	8.09
J-PBH	20	0	7	13	20	0	4	16	23.86	2.71	2.66

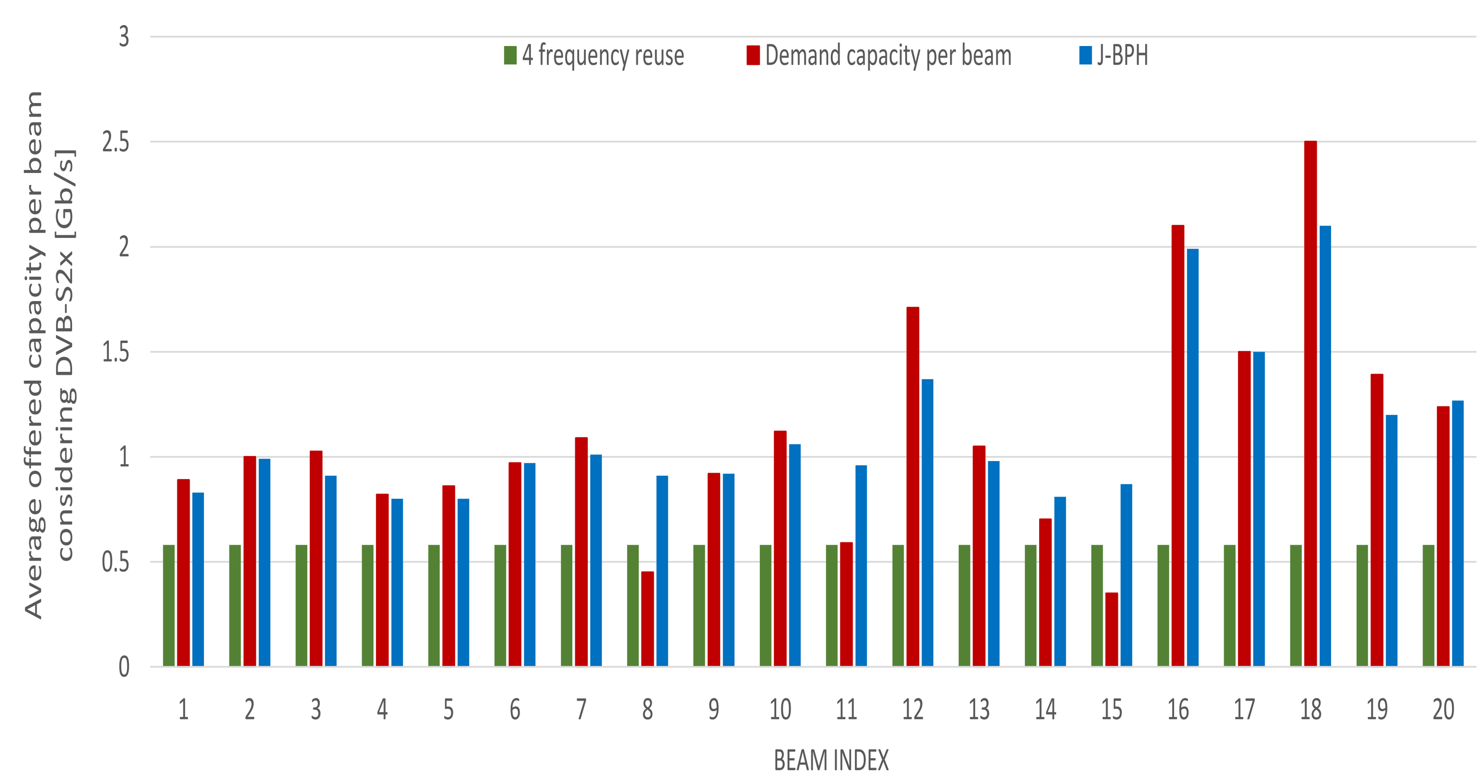


Figure 3. Average throughput (Gb/s) based on DVB-S2X.

Conclusion

The proposed joint precoding and beam hopping scheme provide better performances and it is able to adapt the resources to the demand with respect to the reference scenario.