Random Access Techniques for Satellite Communications

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6. Proposed solution: Smart SPOTiT
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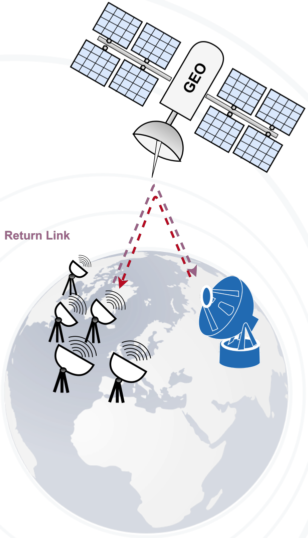
Introduction and context

Satellite systems

- Television, telephony, navigation, observation...
- Hard to reach areas, disasters, maritime...

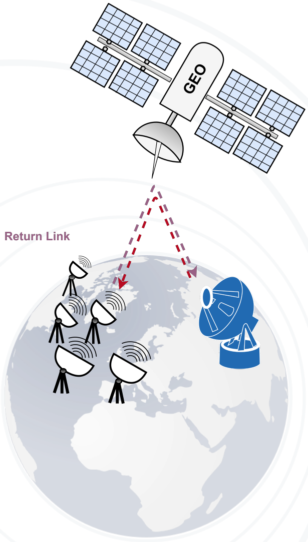
Return link access method

- Random Access for signaling information.
- DAMA for packet transmission.



DAMA can be unsuitable to implement

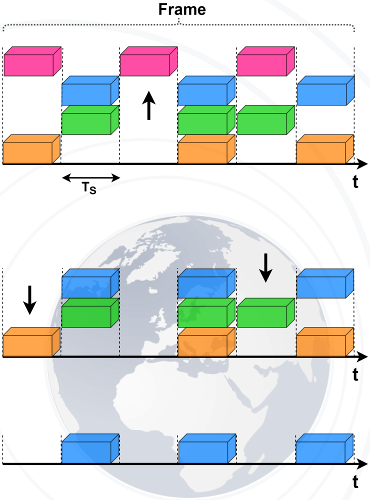
- Sporadic short packets transmission (heavy signaling).
- Resource limitation and under-utilization for big users communities applications.



CRDSA

Characteristics:

- Multiple packet replicas transmission.
- Successive Interference Cancellation at reception.

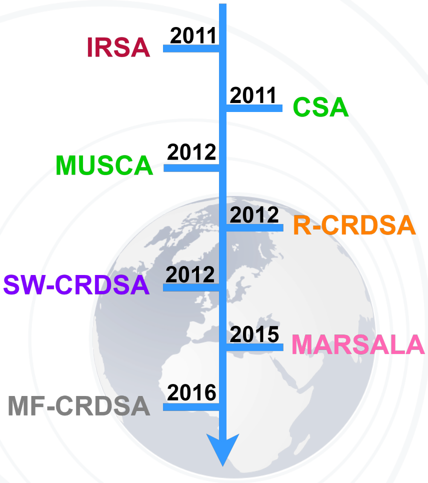


Synchronous Aloha Random Access techniques

Characteristics:

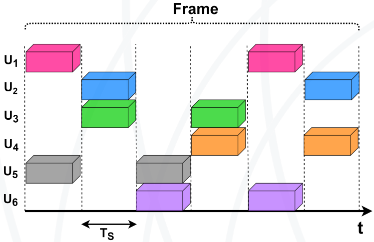
- multiple packet replicas transmission.
- Successive Interference cancellation.
- Irregular number of packet replicas.
- Packets encoding.
- Reservation scheme.
- Sliding window with a slotted frameless scheme.
- Replicas localization and combination prior to decoding.
- Multi-frequency sub-band investigation.

CRDSA



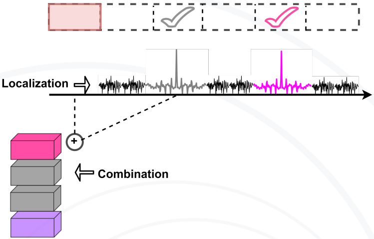
CRDSA's deadlock and role of MARSALA

A deadlock for CRDSA



Solution: MARSALA

1. Localize replicas with correlations.
2. Combine replicas of the same packet before decoding.



SIR comparison when packets are equipowered

Before MARSALA:

$$\mathbf{SIR_{BM}} = \frac{\mathbf{P_{U_5}}}{\mathbf{P_{U_1}}} = 1$$

After combination of MARSALA:

$$\mathbf{SIR_{WM}} = \frac{\mathbf{4 \times P_{U_5}}}{\mathbf{P_{U_1} + P_{U_6}}} = 2$$

Problematic: complexity related to replicas localization

Number of data correlations for one packet decoding on the slot of reference

$$N_{\mathrm{MARSALA}}^{\mathrm{Corr}(1),1} = \underbrace{(N_{\mathrm{S}} - 1)}_{\text{Global localization}} + \underbrace{\sum_{i=1}^{N_{\mathrm{R}}-2} (N_{\mathrm{R}} - 1) \times N_{\mathrm{Coll}}^{\mathrm{Ref}}(1) - i}_{\text{Replicas association}}$$

N_S: number of slots, N_R: number of replicas, N_{Coll}^{Ref}: number of collided packets on the reference time slot.

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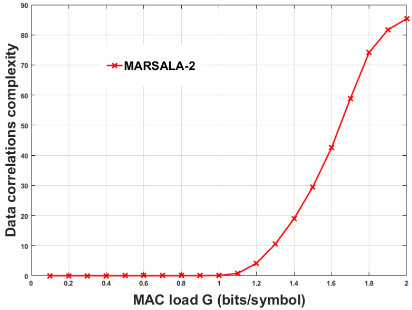


System parameters

- QPSK modulation.
- 3GPP turbo coding of rate 1/3.
- Packet payload of 150 symbols.
- Gold code preambles.
- AWGN channel, $E_S/N_0 = 10$dB.
- Same power for all packets.
- 100 time slots per frame.

Random SPOTiT: Shared POsition Technique for Interfered random Transmissions:

Goal:

- Reduce the localization complexity.

Tracks:

- Design a system that requires less correlations in the localization process.
- Use a two replicas system for complexity matter.

Proposed solution:

- Rely on a **shared information** concerning **packets locations** between the **receiver** and each of the **transmitters** using a PRNG.
- Use the CRDSA multiple preambles system with good auto and cross correlation properties.
- Complementary to CRDSA.

Random SPOTiT

Transmission

$$\text{HID / FID + HID} \rightarrow \boxed{\text{PRNG}} \rightarrow \left\{ \begin{array}{l} S(u,1) \\ S(u,2) \\ P_{U1} \end{array} \right.$$

Reception

Users	HIDs
U_1	HID_1
U_2	HID_2
U_3	HID_3
U_4	HID_4
....	....
....	....

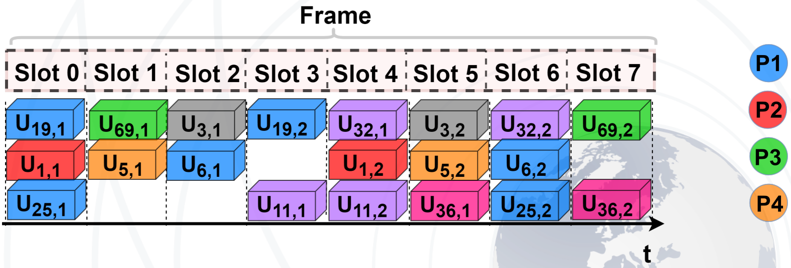
→ **PRNG** →

Users	Position1	Position2	Preamble
U_1	S(1,1)	S(1,2)	P_{U1}
U_2	S(2,1)	S(2,2)	P_{U2}
U_3	S(3,1)	S(3,2)	P_{U3}
U_4	S(4,1)	S(4,2)	P_{U4}
....	....	....	....
....	....	....	....

Receiver's information table

PRNG: PseudoRandom Number Generator

example of Random SPOTiT mechanism



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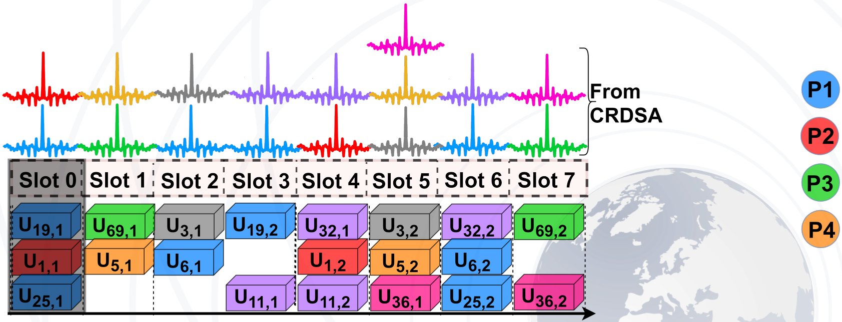

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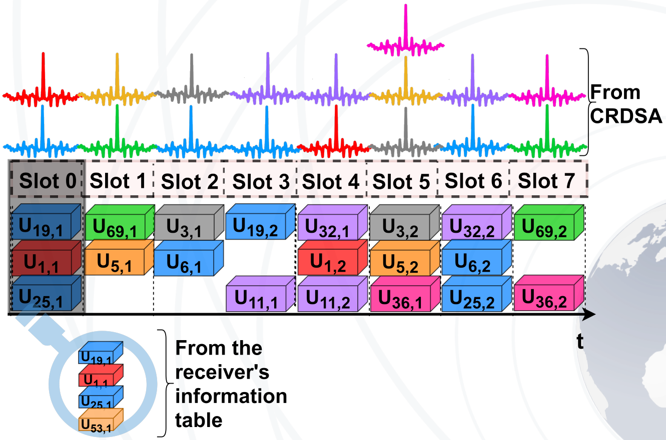
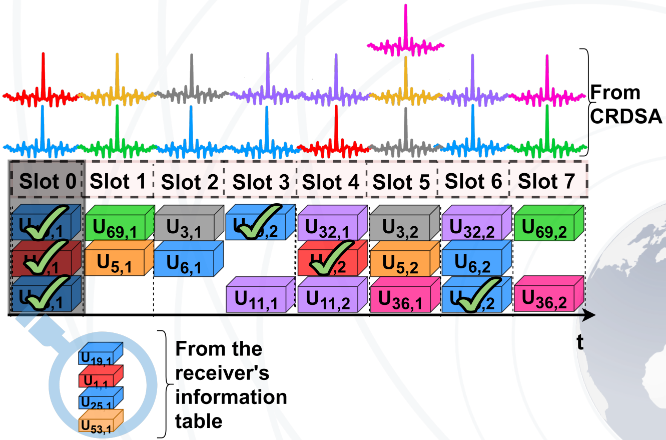


U_U	TS_1	TS_2	P
U_1	S0	S4	P_1
....	....	....	....
U_3	S2	S5	P_5
....	....	....	....
U_{19}	S0	S3	P_1
....	....	....	....
U_{25}	S0	S6	P_1
....	....	....	....
U_{53}	S0	S7	P_1

example of Random SPOTiT mechanism



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....	....	....	....
U_{53}	S0	S7	P_1

Random SPOTiT: complexity

Number of data correlations for one packet decoding, using a preamble p

$$N^{\mathrm{Corr}(1),p}_{\mathrm{SPOTiT}} = (N_{\mathrm{R}} - 1) \times N^{\mathrm{Ref}}_{\mathrm{pot}}(p)$$

N^{Ref}_{Coll}: Number of potential users using the detected preamble p that can transmit on the reference time slot.

In case of two replicas per packet

MARSALA

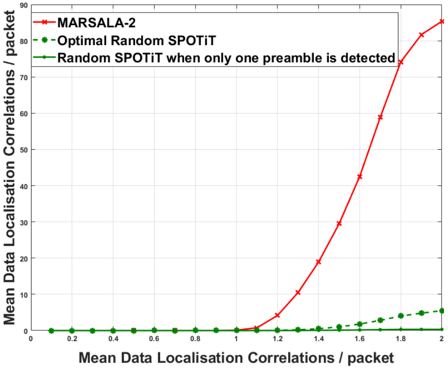
$$N^{\mathrm{Corr}(1)}_{\mathrm{MARSALA2}} = (N_{\mathrm{S}} - 1)$$

Random SPOTiT

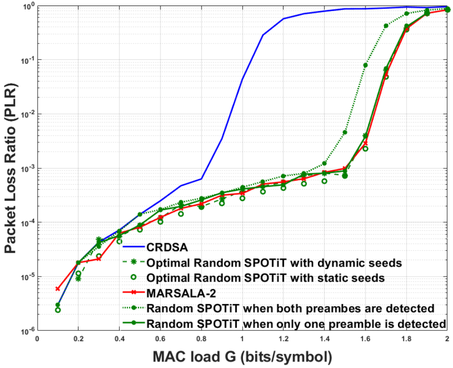
$$N^{\mathrm{Corr}(1),p}_{\mathrm{SPOTiT},2} = N^{\mathrm{Ref}}_{\mathrm{pot}}(p)$$

Random SPOTiT: Performance

Number of data correlations

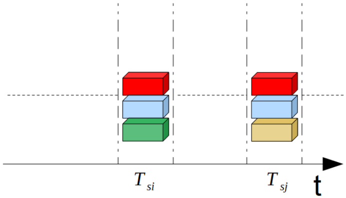


Packet Loss Ratio



Equipowered packets of 150 symbols, 100 time slots per frame, 3GPP turbo coding of rate 1/3, QPSK modulation gold code preambles, AWGN channel, E_S/N_0 = 10dB, 2 replicas/packet.

Problematic: loop phenomenon



$$SIR = \frac{4 \text{ x } P}{4\text{x}P + P + P}$$

Cas d'equiPuissance

$$SIR = \frac{2}{3}$$

Higher packet error rate with a floor.

Smart SPOTiT: Principle

Goal:

- Manage and eliminate data loops between packets with packet simple localization.

Tracks:

- Design a manageable system that can provide a smart distribution with a **one time signaling information** at the logon phase.
- Use a **two replicas** per packet system.

Proposed solution:

- Rely on a **power of two** system and **cyclic shifting** to define the **optimal distribution**.
- This will make sure **no loops** are created and that **one of the two replicas has no other collision with a packet having the same preamble**.

Smart SPOTiT: parameters

N_S : number of time slots per frame.

$N_P = \frac{N_S}{2}$: number of preambles.

N_R : number of replicas.

$N_U = \frac{N_S \times (N_S - 1)}{2}$: number of users.

$N_L = log_2(N_S)$: number of distribution levels.

Distribution of time slots positions for each level

Level 1: $\{0..M_1..N_S\text{-}1\}$

Level 2: $\{0..M_{21}..M_1\}$ $\{M_1+1..M_{22}..N_S\text{-}1\}$

Level 3: {.....} {.....} {.....} {.....}

At each level, there are N_P preamble groups.

Smart SPOTiT: example

$N_S = 8$
$N_P = 4$
$N_R = 2$
$N_L = 3$
$N_U = 28$

P1
P2
P3
P4

Level 1
Slots set: {0..3..7}
Preamble groups: 4 groups of 4 users

Group 1			Group 2			Group 3			Group 4		
U_1	0	4	U_5	0	5	U_9	0	6	U_{13}	0	6
U_2	1	5	U_6	1	6	U_{10}	1	7	U_{14}	1	7
U_3	2	6	U_7	2	7	U_{11}	2	4	U_{15}	2	4
U_4	3	7	U_8	3	4	U_{12}	3	5	U_{16}	3	5
	P_1			P_2			P_3			P_4	

Level 2
Slots set: {0..1..3} and {4..5..7}
Preamble groups: 4 groups of 2 users

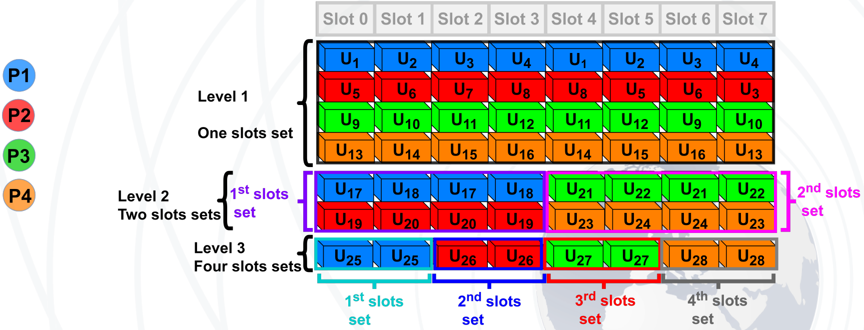
Group 1			Group 2			Group 3			Group 4		
U_{17}	0	2	U_{19}	0	3	U_{21}	4	6	U_{23}	4	7
U_{18}	1	3	U_{20}	1	2	U_{22}	5	7	U_{24}	5	6
	P_1			P_2			P_3			P_4	

Level 3
Slots set: {0..1}, {2..3}, {4..5} and {6..7}
Preamble groups: 4 groups of 1 users

Group 1			Group 2			Group 3			Group 4		
U_{25}	0	1	U_{26}	2	3	U_{27}	4	5	U_{28}	6	7
	P_1			P_2			P_3			P_4	

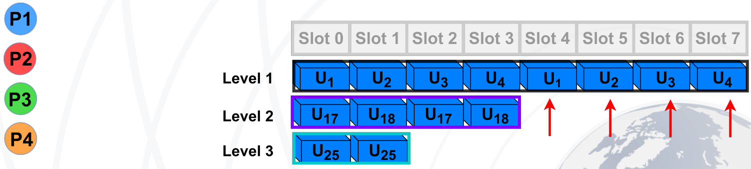
Smart SPOTiT: example

Worst case scenario of the frame structure



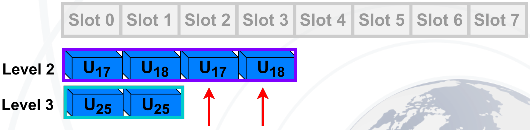
Smart SPOTiT: example

Worst case scenario for the blue preamble



Smart SPOTiT: example

Worst case scenario for the blue preamble



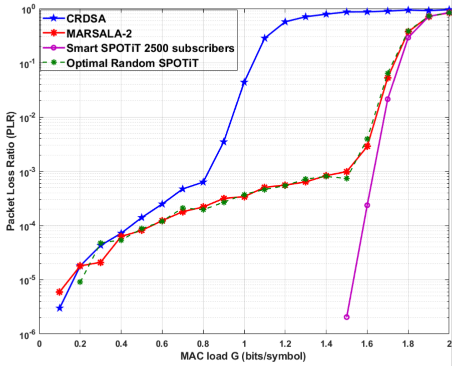
Smart SPOTiT: example

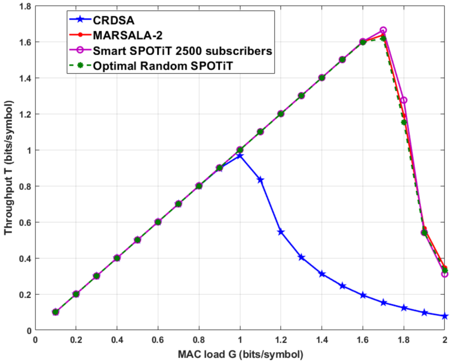
P1
P2
P3
P4

Worst case scenario for the blue preamble

Smart SPOTiT: Performance

Packet Loss Ratio | **Throughput (bits/symbol)**





Equipowered packets of 150 symbols, 100 time slots per frame, 3GPP turbo coding of rate 1/3, QPSK modulation gold code preambles, AWGN channel, E_S/N_0 = 10dB, 2 replicas/packet.

Ongoing related work

- Detailed complexity evaluation of Random SPOTiT: Total number of preamble and data correlations per frame, select the least complex scheme.
- Design of a non power of two Smart SPOTiT with non standard parameters: select among the different schemes the simplest one.
- Define an asynchronous extension of Random SPOTiT that goes along with ACRDA.

Conclusion

- Shared knowledge regarding replicas positions + Pseudo orthogonal preambles.
- Reduced complexity related to the number of localization correlations without degrading performance.
- A deterministic approach for random transmissions.
- Loop elimination with a maximum number of users and a simple packet localization.
- Disappearance of the error floor and thus better PLR performance.

Thank you for your attention ☺