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Radio Resource Management for next generation DVB-RCS systems

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- SatSix DAMA Algorithm
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 - Control-theoretic Bandwidth-on-Demand (BoD) algorithm
 - Control of the link utilization
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Introduction on Radio Resource Management (RRM)

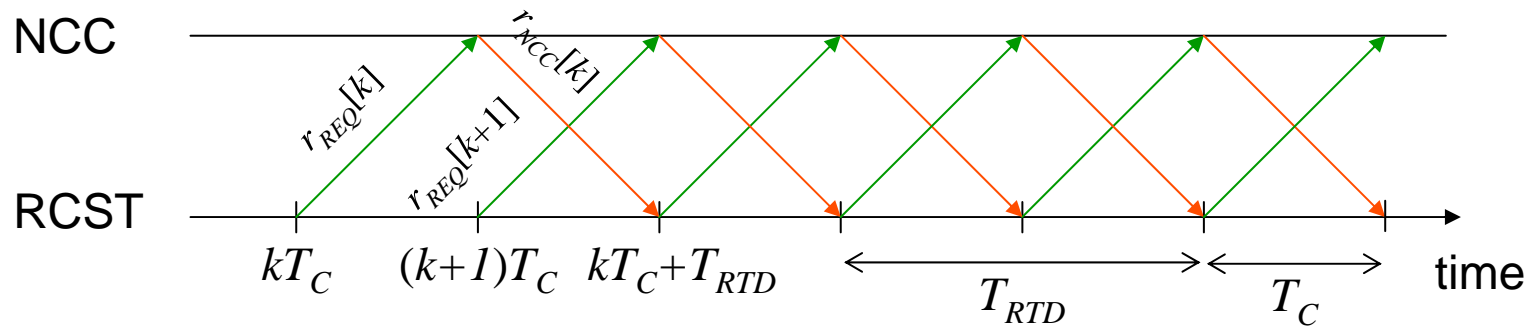


- Paper based on the work performed within the IST FP6 SATSIX project, which is studying and implementing a DVB-RCS/S2 satellite systems

- Radio Resource Management (RRM) objective is to propose efficient resource management for satellite systems by means of
 - Fade Mitigation Techniques
 - Algorithms counteracting attenuations by enabling link adaptation (modulation, coding and symbol rate) according to the propagation conditions
 - Connection Admission Control
 - Algorithm in charge of deciding upon the admission of new calls
 - DAMA
 - Algorithms in charge of dynamically allocating the link capacity on demand

- The presentation focuses on the DAMA algorithms

SatSix DAMA Algorithm BoD Mechanism



■ Control period T_C

- Every RCST has a periodic opportunity to send capacity requests to the NCC, with period T_C

■ Round Trip Delay T_{RTD}

- The delay between the request and the associated capacity allocation is fixed and equal to the Round Trip Delay T_{RTD} (about 0.6 s)



The objective is twofold:

- If the link load is high, the RCSTs must utilize all the requested bandwidth
 - Full link utilization
- If the link load is low, the RCSTs can waste some requested bandwidth
 - A more aggressive BoD policy can be adopted to reduce queuing delays

- Problem
 - The same BoD policy leads to a different percentage of wasted bandwidth (i.e., to a different link utilization)

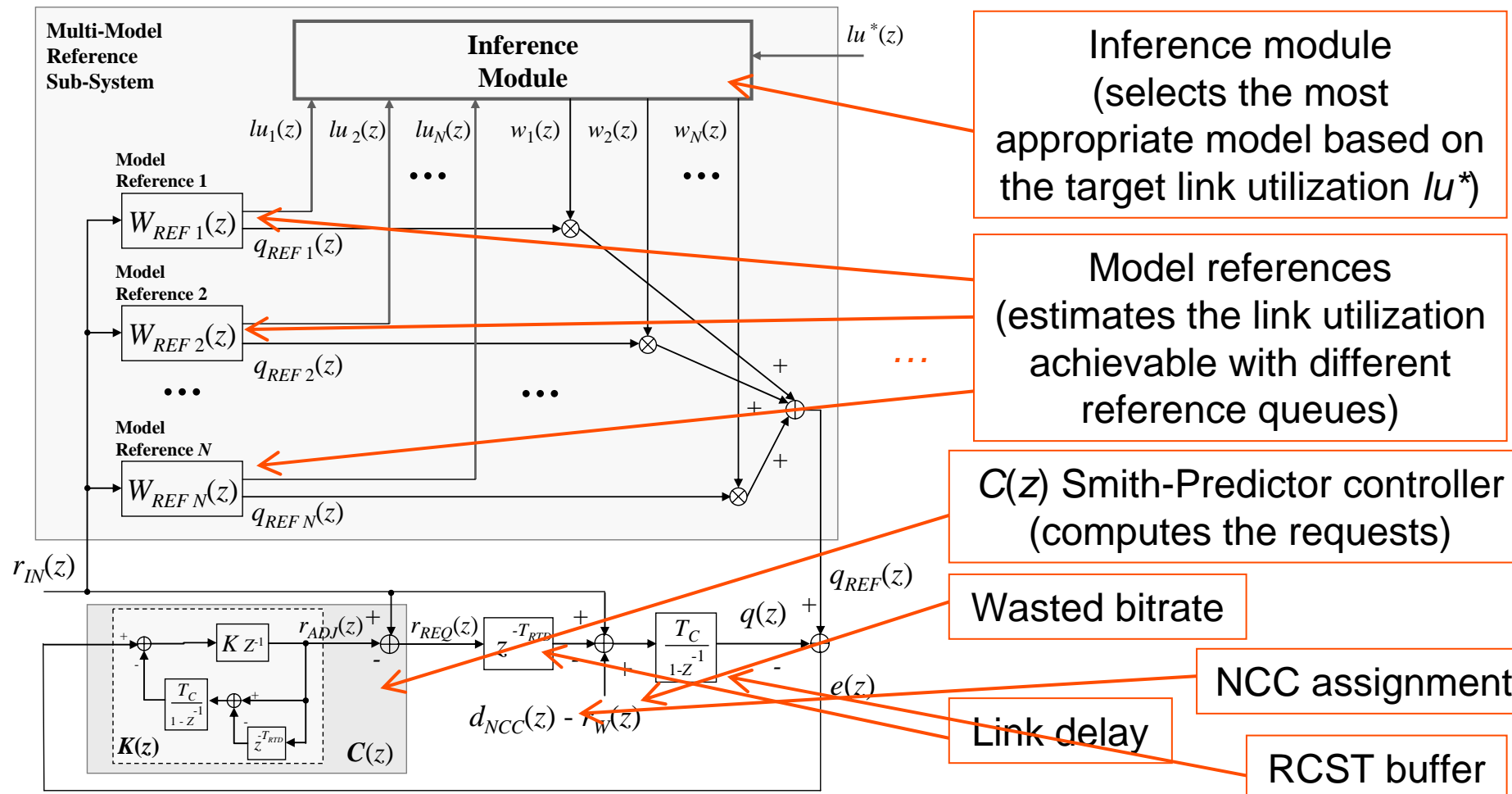


Algorithm rationale

- NCC computes the *target link utilization* (lu^*) based on:
 - Received RCST bandwidth requests
 - Link capacity available on-demand
- RCSTs compute the requests aimed at achieving the *target link utilization* (lu^*) based on:
 - Measured buffer queue length
 - It take into account the unsatisfied requests
 - Measured input traffic
 - It is used to
 - estimate the incoming traffic rate
 - set the BoD policy to achieve lu^*

Algorithm description

Overall scheme



Inference module (selects the most appropriate model based on the target link utilization lu^*)

Model references (estimates the link utilization achievable with different reference queues)

C(z) Smith-Predictor controller (computes the requests)

Wasted bitrate

NCC assignment

Link delay

RCST buffer

Radio Resource Management (RRM) Control-theoretic BoD algorithm



■ Request computation

$$r_{REQ}[k] = \frac{1}{T_C} q[k] - \sum_{i=1}^{T_{RTD}} r_{REQ}[k-i] + (1-\alpha) \sum_{i=0}^{T_{RTD}} r_{IN}[k-i]$$

measured queue length

measured input rate

■ Prediction parameter (α)

- $\alpha = 1$: *full link utilization* (no anticipated request)
- $\alpha = 0$: *aggressive policy* (prediction part of the request equal to the traffic received in the last Round Trip Delay)

Radio Resource Management (RRM) Control of the link utilization



To achieve a given target utilization, α is computed based on traffic measures

- **STEP1: 6 models are computed (Multi-Model Reference Control methodology), whose dynamics are driven by the following equations:**

$$q_i'[k+1] = q_i[k] + T_c r_{IN}[k] - T_c r_{REQ,i}[k - T_{RTD}]$$

$$q_i[k+1] = \max(0, q_i'[k+1])$$

$$r_{REQ,i}[k] = \frac{1}{T_C} q_i[k] - \sum_{i=1}^{T_{RTD}} r_{REQ,i}[k-i] + (1 - \alpha_i) \sum_{i=0}^{T_{RTD}} r_{IN}[k-i]$$

with $\alpha_1 = 0$; $\alpha_2 = 0.2$; $\alpha_3 = 0.4$; $\alpha_4 = 0.6$; $\alpha_5 = 0.8$; $\alpha_6 = 1$

measured input rate

Radio Resource Management (RRM)

Control of the link utilization



- STEP2: The i -th model allows one to compute its wasted bitrate:

$$r_{wi}[k] = -\min(0, q_i'[k]) / T_C$$

and, therefore, the average link utilization of the i -th model:

$$\bar{lu}_i[k] = w\bar{lu}_i[k-1] + (1-w)lu_i[k]$$

with

$$lu_i[k] = \frac{r_{REQi}[k - T_{RTD}] - r_{wi}[k]}{r_{REQi}[k - T_{RTD}]}$$

$$w = 0.975$$

Radio Resource Management (RRM) Control of the link utilization



■ STEP3: Inference of α based on $lu^*[k]$

If $lu^*[k] \leq \bar{lu}_1[k]$, $\alpha = 0$;

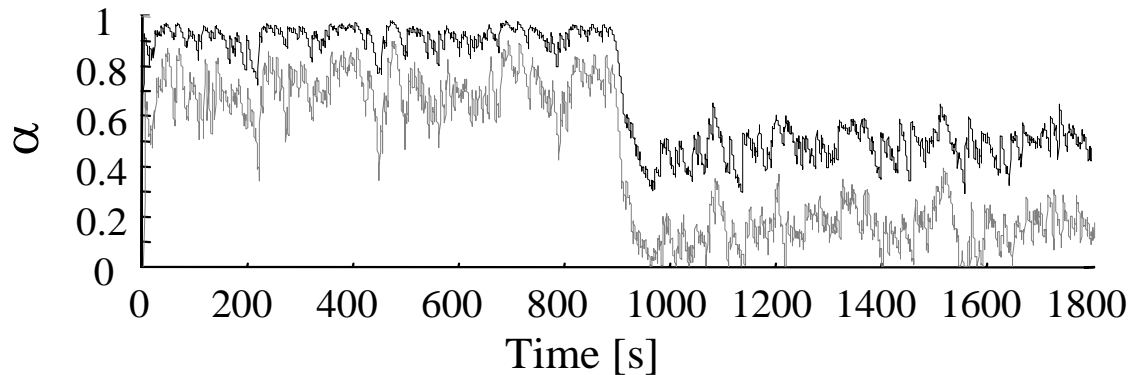
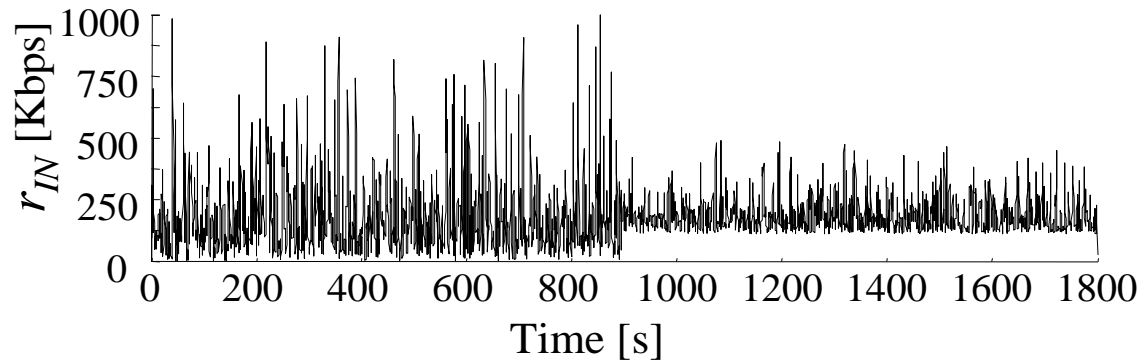
If $\bar{lu}_i[k] < lu^*[k] \leq \bar{lu}_{i+1}[k]$, $\alpha = \alpha_i \left(\frac{\bar{lu}_{i+1}[k] - lu^*[k]}{\bar{lu}_{i+1}[k] - \bar{lu}_i[k]} \right) + \alpha_{i+1} \left(\frac{lu^*[k] - \bar{lu}_i[k]}{\bar{lu}_{i+1}[k] - \bar{lu}_i[k]} \right)$;

If $lu^*[k] \geq \bar{lu}_6[k]$, $\alpha = 1$;

Radio Resource Management (RRM) Control of the link utilization



Example of RCST aiming at lu^*



$lu^* = 97.5\%$ ———
 $lu^* = 90\%$ - - - -

Radio Resource Management (RRM)

Control of the link utilization



lu^* : target link utilization

\bar{lu} : average link utilization

\bar{q} : average queue length;

\bar{d} : average queuing delay;

$\bar{\alpha}$: average α

lu^* [%]	\bar{lu} [%]	\bar{q} [kbits]	\bar{d} [s]	$\bar{\alpha}$
100	100	163.5522	0.9	1
97.5	97.45	85.3641	0.4696	0.7137
95	95.36	74.4468	0.4089	0.6085
92.5	92.57	64.0992	0.3530	0.4884
90	90.64	58.0036	0.3194	0.4109
87.5	87.85	50.0132	0.2751	0.2969



The target link utilization lu^* is computed based on the link load

- The NCC computes the target link utilization as the ratio of the (averaged) low-priority traffic rate C_{LP} and the available capacity C_{AV} :

$$lu^*[k] = \frac{\bar{C}_{LP}[k]}{\bar{C}_{AV}[k]} = \frac{w\bar{C}_{LP}[k-1] + (1-w)C_{LP}[k]}{w\bar{C}_{AV}[k-1] + (1-w)C_{AV}[k]}$$

- The low-priority traffic rate C_{LP} is estimated as:

$$\hat{C}_{LP}[k] = w\hat{C}_{LP}[k-1] + (1-w)\hat{C}_{LP}[k]$$

$$\text{where } \hat{C}_{LP}[k] = C_{REQ}[k-i-T_{RTD}]lu^*[k-i-T_{RTD}]$$

Radio Resource Management (RRM) Simulation results



Tab. 1: Traffic sources– $\eta(k)$ is the traffic profile defined in Tab. 2 .

Source	Highly Regular	Regular	Bursty	Highly Bursty
Constant traffic rate [kbps]	$\eta(k) \cdot 375$	$\eta(k) \cdot 250$	$\eta(k) \cdot 125$	0
Bursty traffic mean rate [kbps]	$\eta(k) \cdot 250$	$\eta(k) \cdot 375$	$\eta(k) \cdot 500$	$\eta(k) \cdot 625$

Tab. 2: Simulation traffic.

Sim. #	Type of STs	Traffic profile
1	1 ST with varying traffic, from H. Bursty to H. Regular (Fig. 7)	$\eta(k) = 0.3 u_{,1}(k)$
2	ST _{1,2} : H. Regular, ST _{3,4} : Regular, ST _{5,6} : Bursty, ST _{7,8} : H. Bursty	$\eta(k) = 0.7 u_{,1}(k) + 0.3 \sin(kT_c \pi / \text{sim_length})$
3	ST _{1,2} : H. Regular, ST _{3,4} : Regular, ST _{5,6} : Bursty, ST _{7,8} : H. Bursty	$\eta(k) = 0.8 u_{,1}(k)$

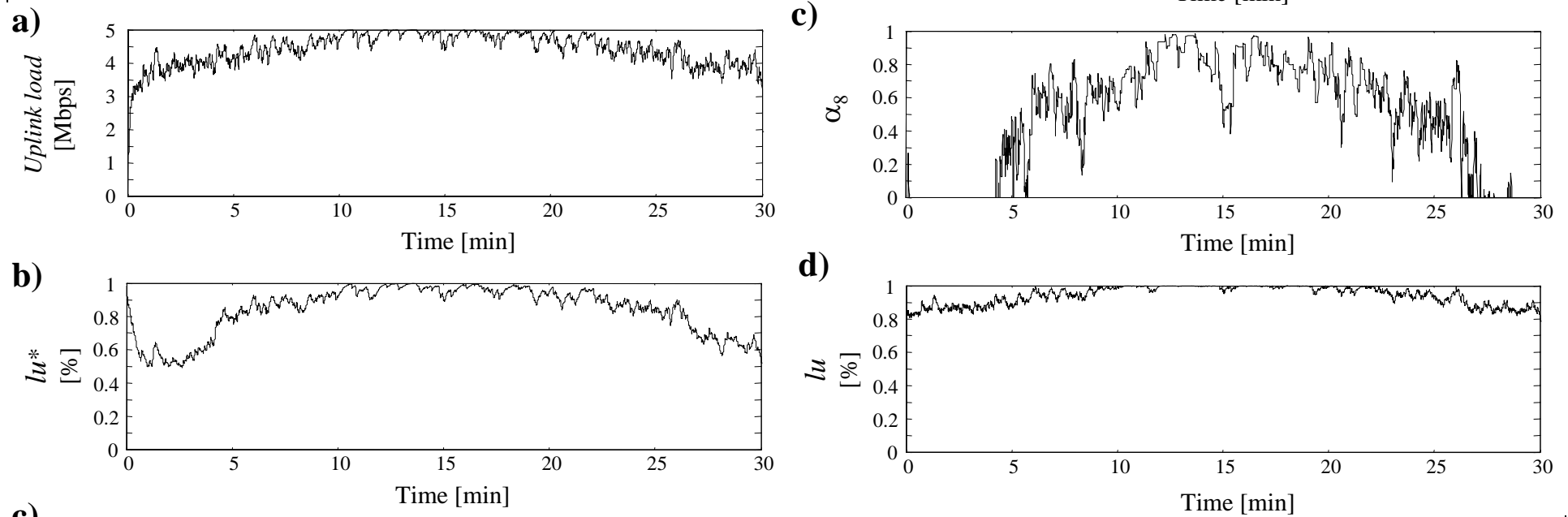
Tab. 3: Simulation parameters.

Sim. #	T_C	T_{RTD}	W_{lu}	C_{av}	Sim_length	FCA
1	0.3s	$2T_C = 0.6s$	0.975	5 [Mbps]	$6000 \cdot T_C = 30 \text{ min}$	No
2	0.3s	$2T_C = 0.6s$	0.975	5 [Mbps]	$6000 \cdot T_C = 30 \text{ min}$	No
3	0.3s	$2T_C = 0.6s$	0.975	5 [Mbps]	$6000 \cdot T_C = 30 \text{ min}$	Yes

Radio Resource Management (RRM) Simulation results



Example of I_u^* and α adaptation



Radio Resource Management (RRM) Simulation results



Without FCA

\bar{lu} : average link utilization; \bar{q} : average queue length; \bar{d} : average queuing delay; $\bar{\alpha}_i$: average α of ST_i

Sim. Run	\bar{lu} [%]	\bar{q} [bits]	\bar{d} [s]	$\bar{\alpha}_1$	$\bar{\alpha}_2$	$\bar{\alpha}_3$	$\bar{\alpha}_4$	$\bar{\alpha}_5$	$\bar{\alpha}_6$	$\bar{\alpha}_7$	$\bar{\alpha}_8$
$\alpha \equiv 1$	100	561.11	0.9845	1							
Adaptive α, lu^*	82.40	271.01	0.4668	0.14	0.24	0.23	0.35	0.36	0.36	0.48	0.48

With FCA

\bar{q} : average queue length; \bar{d} : average queuing delay

Sim. Run	\bar{r}_{REQ} [kbits]			\bar{r}_{NCC} [kbps]			\bar{q} [kbits]		\bar{d} [s]	
	Total	ST_1	ST_8	Total	ST_1	ST_8	ST_1	ST_8	ST_1	ST_8
$\alpha \equiv 1$	4164.4	532.31	492.35	5000	639.46	580.08	121.05	181.38	0.2252	0.3321
Adaptive α, lu^*	5072.9	655.06	620.46	5000	633.71	598.33	128.66	152.88	0.2383	0.2997



- Radio Resource Management techniques are in charge of guaranteeing an efficient use of the valuable satellite capacity

- The presentation focused on the BoD protocol
 - Based on control-theory
 - Capable of achieving a given link utilization efficiency based on traffic measures
 - It adapts its policy on the traffic characteristics and on the link load:
 - If the network load is scarce, the delay performance is favoured since the network resources are over-provisioning
 - If the network is load is high, the utilization efficiency is favoured, to reduce the congestion occurrence probability by reducing bandwidth wastes