Configuration the Communication on FlexRay the case of the static segment

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Joint work with Mathieu GRENIER and Lionel HAVET

FlexRay configuration

- Extremely complex problem:
  - Mixed of TT and ET scheduling
  - Tightly linked with task scheduling
  - Large number of parameters (>70)
  - AUTOSAR constraints (OS, COM, etc)
  - …
- Design objectives should be first clearly identified:
  - Minimum bandwidth to use cheap components (2.5 Mbit/s, 5MBit/s ?)
  - Enable incremental design ?
  - Carry-over of ECUs ?
- No chance to solve the pb optimally – too many free variables, sub-problems alone are NP-hard

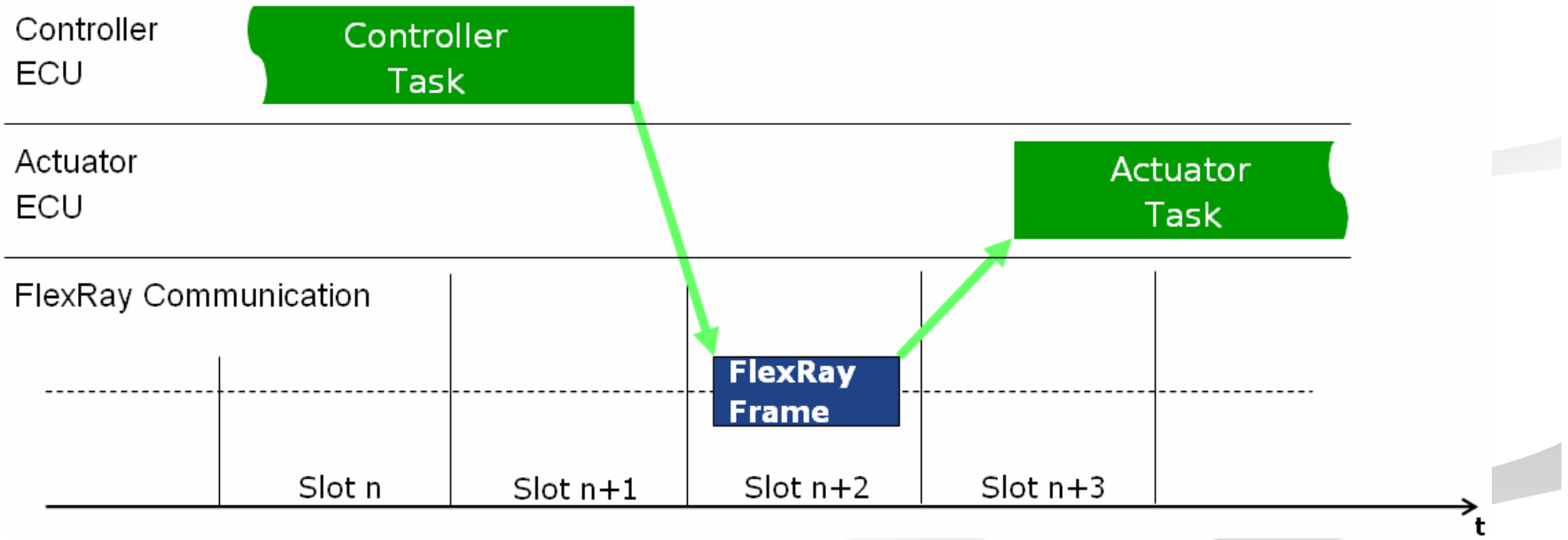
Requirements on FlexRay

- Performance requirements: both run-time (response times, jitters, etc.) and End-of-Line/Garage flash update
- Incrementality requirements: additional functions or ECUs
- Dependability requirements: fail-silence, babbling idiot, deadline failure probability under EMI, …
- Platform requirements: platform wide frames (e.g., NM), carry-over of ECUs, able to deal with com. controller + CPU + Autosar stack performances, …

Tasks run either
synchronously or asynchronously
wrt the communication cycle

Case 1 : synchronous case (1 / 2)

- Best possible results with regard to signal latency and dependability



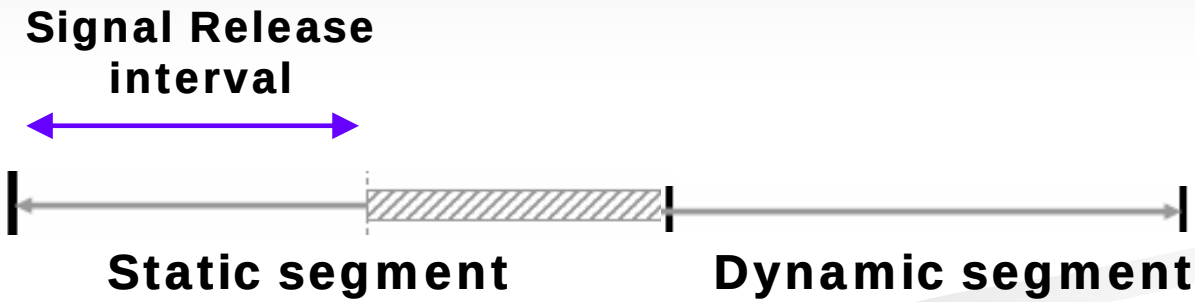
Picture from [1]

Case 1 : synchronous case (2/2)

- But strong constraints:
  - require Static Cyclic Scheduling
  - impose to re-design existing functions / design according to the bus configuration
  - task periods constrained by FlexRay/Autosar rules (cycle repetition, e.g. 10, 20, 40, 80ms with a cycle=5ms)
    - might require to artificially increase the frequency of some tasks → CPU load
  - length of the communication cycle is crucial

Case 2 : asynchronous case

- Signals produced at variable time points in the round – depends on the scheduling of tasks



- Signal freshness constraint imposes a range of slots for transmission and a min. frequency (every *x* cycles)

Scope of the study

Assumptions on FlexRay (1/2)

1. Signals with up to 2.5 ms constraints are transmitted in the ST segment:
   - DYN segment < 2.5ms
   - Here : ST = 3ms, DYN (+NIT+SW) = 2ms

2. Frames data payload = 16 bytes

Bit Rate (Mbit/s)	2.5	5	10
$gNumberOfStaticSlots$	**27**	**51**	**93**

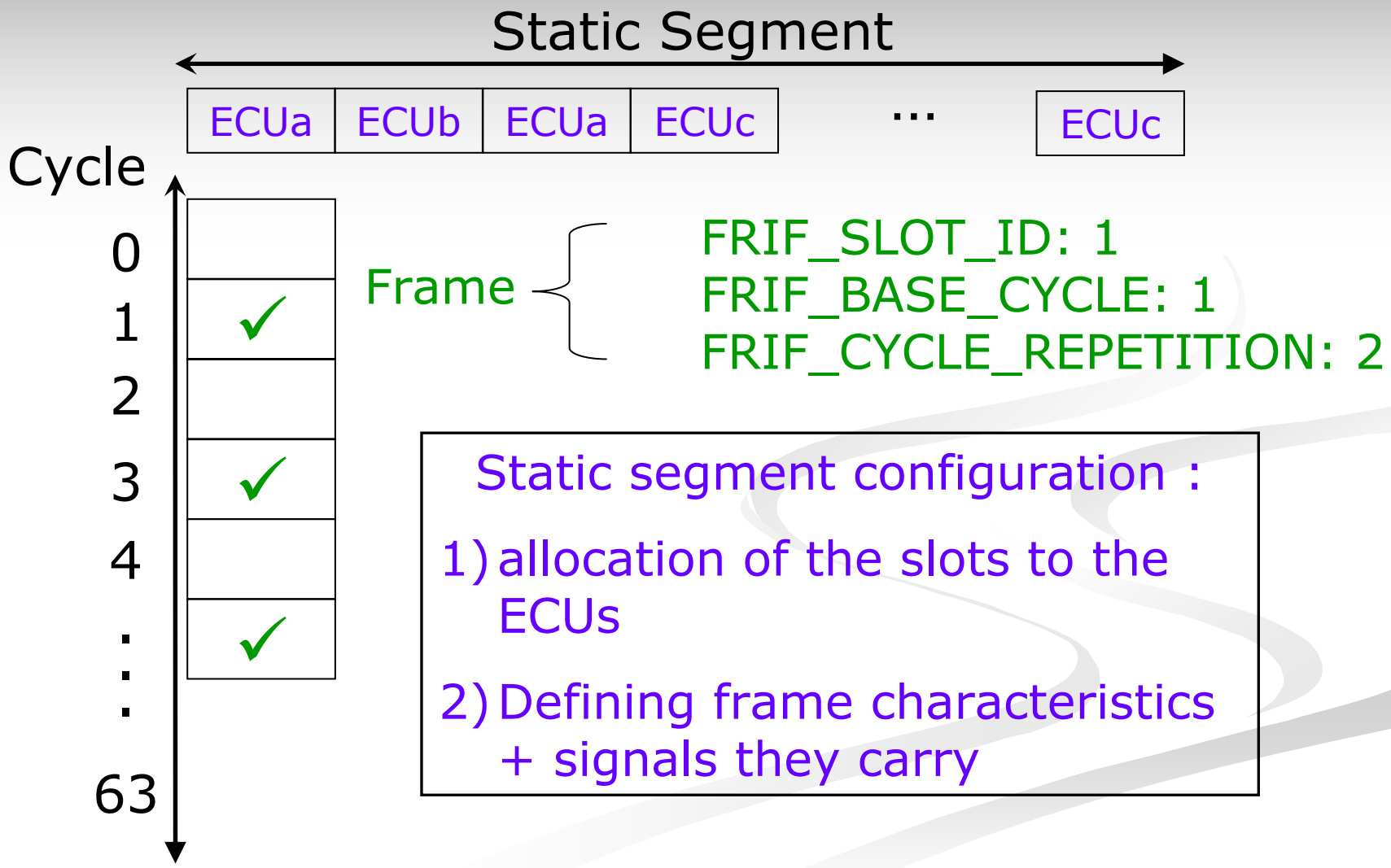
Assumptions on FlexRay (2/2)

3. Only one communication channel is used
4. A signal is produced with given period and offset
5. Deadlines ≤ Periods: no buffer overwrite
6. One signal per frame: no signal multiplexing
7. FlexRay is used in the context of AUTOSAR

an AUTOSAR frame is defined by:

- FRIF_SLOT_ID: static segment slot
- FRIF_BASE_CYCLE: first transmission cycle
- FRIF_CYCLE_REPETITION: must be a power of two

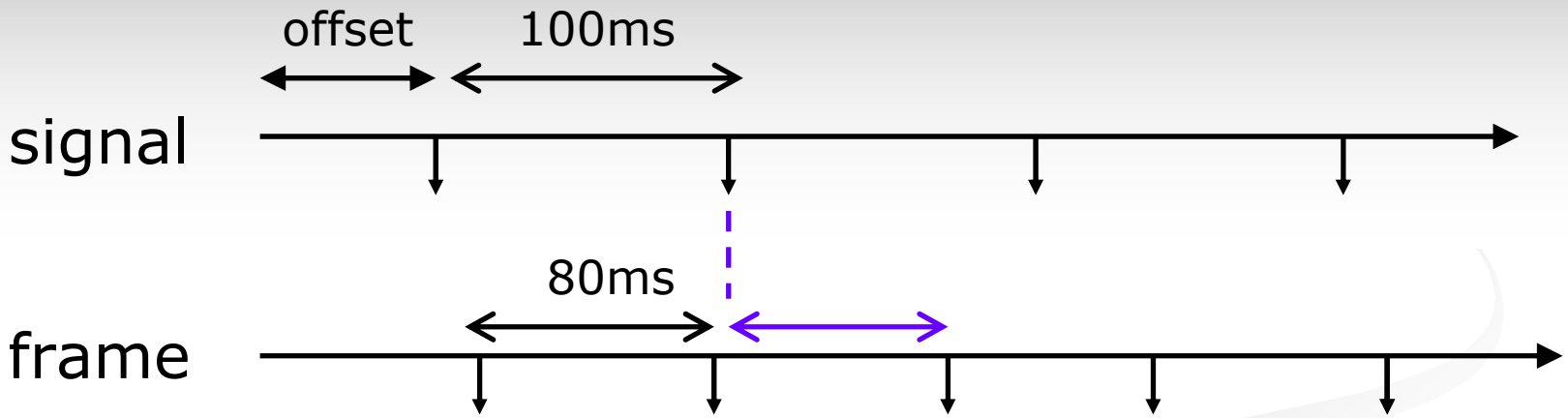
Communication schedule



Static segment configuration :

1) allocation of the slots to the ECUs
2) Defining frame characteristics + signals they carry

Timing Constraints: asynchronous case



Signal age (or signal response time): time between production of a signal and end of transmission of the first frame containing the signal

Max signal age = 80ms here

Problems addressed in the paper

1. Check timing constraints :
   - Non-schedulability tests for a set of signals - if non-schedulable is returned then no feasible configuration exists
   - An exact schedulability analysis of a given configuration

2. Algorithm to construct the configuration starting from the set of signals –
   Objective: minimize the # of slots used while meeting timing constraints

Sketch of the algorithm: "Best Slot First" (BSF)

- For each slot and each ECU, compute the "maximum" number of signals the slot can transmit:
  - A heuristic is used to build the set of frames for each slot / ECU
- Keep the slot/ECU choice that maximizes the number of signals transmitted
- Repeat until there is no signal or no slot left

Performance evaluation

Performance metrics:

1. Percentage of feasible signal sets
2. # of slots used in the static segment

Benchmark against a naïve strategy called Randomized Slot Selection (RSS)

Experimental setup

- 8 bytes signals in 16 bytes frames (no PDU multiplex.)
- Static segment = 3ms – communication cycle = 5ms
- 10Mbit/s FlexRay – 93 slots
- Signals generated with NETCARBENCH
- Freshness constraints :
  - Case 1: Equal to periods
  - Case 2 : Equal to min(period, 30ms)
- Available bandwidth (ST seg. alone – "power of two" constraints not considered) ≈ 1.2Mbit/s (out of 6Mbit/s)
- In our experiments (case 1), 1Mbit/s of data leads to 88 slots on average

Deadlines equal to periods

of feasible signal sets out of 100

signal rate (kbit/s)	250	400	550	700	850	1000
BSF	100	100	100	100	100	100
RSS	96	61	12	0	0	0

# of slots used in the static segment (out of 93)

signal rate (kbit/s)	250	400	550	700	850	1000
BSF	25.1	37.3	49.9	65.9	77	88
RSS	89.2	93	93	NA	NA	NA

Deadlines smaller than periods

of feasible signal sets out of 100

signal rate (kbit/s)	250	400	550	700	850	1000
Test1	100	100	100	100	**100**	**85**
Test2	100	100	100	100	**35**	0
BSF	100	100	100	**52**	**2**	0
RSS	96	68	**8**	0	0	0

- 850 kbit/s : Test2 says that 35 might be feasible while BSF only find 2 feasible configurations - is test 2 optimistic or BSF inefficient ?

Conclusions / Perspectives

- Solutions to configure the static segment of FlexRay considering automotive constraints → implemented in a prototype generating FIBEX file
- Tests help to identify signals that would be best transmitted in the dynamic segment
- Asynchronous tasks : response times can be larger than on CAN
- Frame packing is needed – 2 levels:
  - Packing signals into 8-bytes PDU at the AUTOSAR communication level
  - Packing PDUs into frames at the AUTOSAR FlexRay Interface level

Questions, feedback?
please contact me at
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INTERFERENCE OF SCS TASKS ON FPS TASKS

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