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# Message Scheduling for the FlexRay protocol

The Dynamic Segment

Presented By

# Message Scheduling for the FlexRay protocol

The  Dynamic Segment

Presented By
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2013 – 5 – 30

# Outline

- Introduction
- FlexRay protocol
- Message Schedule for the DS
- Message Grouping
- Optimal Scheduling of Messages
- Results
- Conclusion

# Introduction

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- In this paper bounds on the generation times and the timing requirements of the signals is taken into consideration to propose a reservation-based scheduling approach that preserves the flexible medium access of the DS

# FlexRay Protocol

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- The arbitration procedure ensures that only frames with a FID that equals the current value of the slot counter can be transmitted

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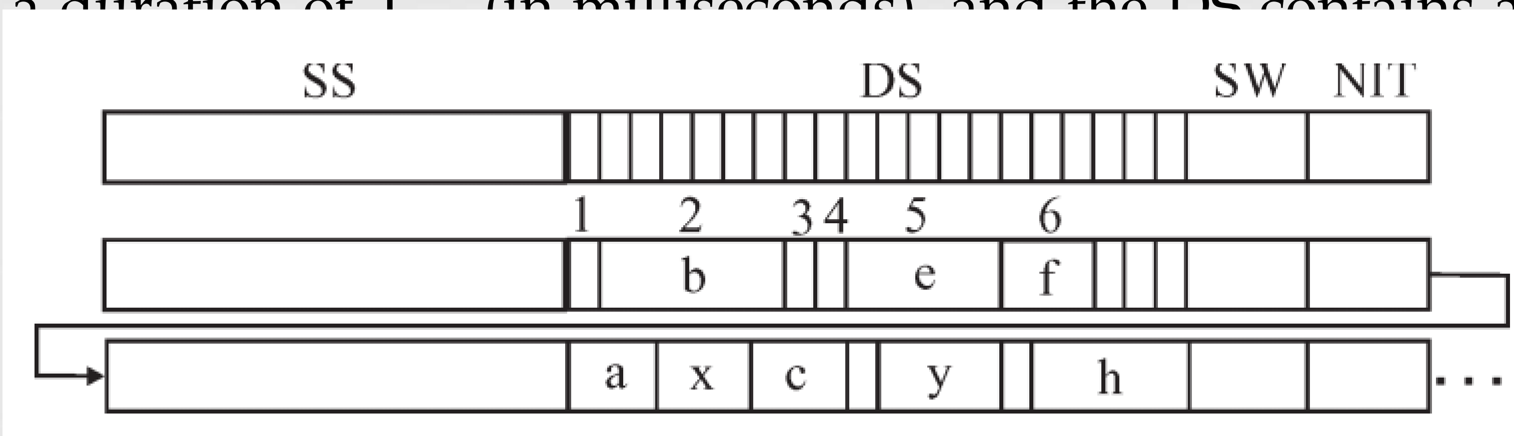


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$$l_m^n = \lceil (s_m^n \cdot 16 \text{ bits} + s_m^n \cdot 4 \text{ bits} + O_{\mathrm{F}})\, \tau_{\mathrm{bit}} / T_{\mathrm{MS}} \rceil$$

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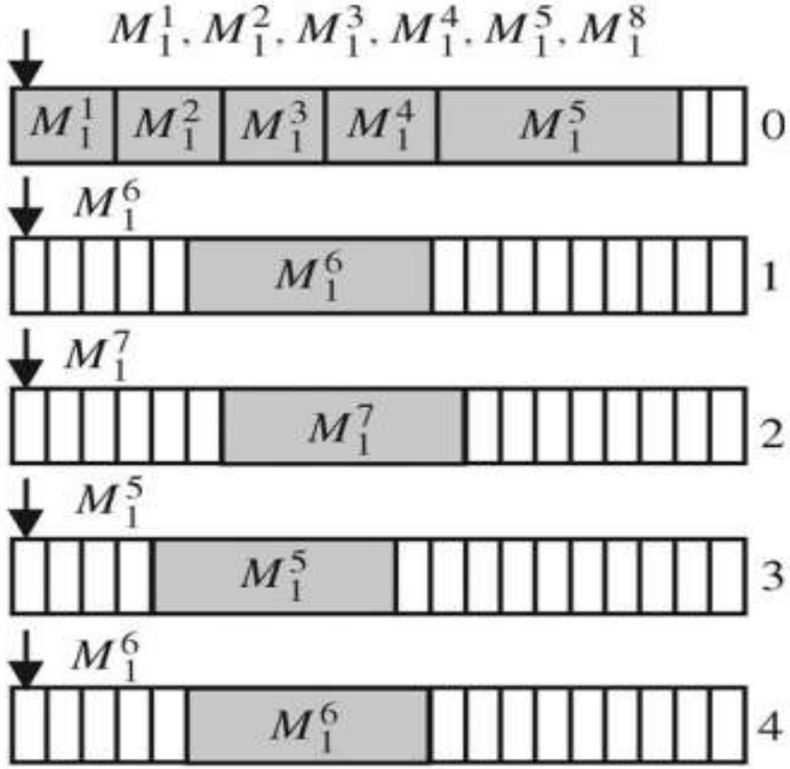
- How DM fails?

# Previous Work

| $M_1^n$ | $lm_1^n$ [MS] | $dm_1^n$ [ms] | $FID$ |
|---|---|---|---|
| $M_1^1$ | 2 | 15 | 1 |
| $M_1^2$ | 2 | 15 | 2 |
| $M_1^3$ | 2 | 15 | 3 |
| $M_1^4$ | 2 | 15 | 4 |
| $M_1^5$ | 40 | 15 | 5 |
| $M_1^6$ | 40 | 15 | 6 |
| $M_1^7$ | 40 | 15 | 7 |
| $M_1^8$ | 112 | 25 | 8 |



# FlexRay Software Architecture

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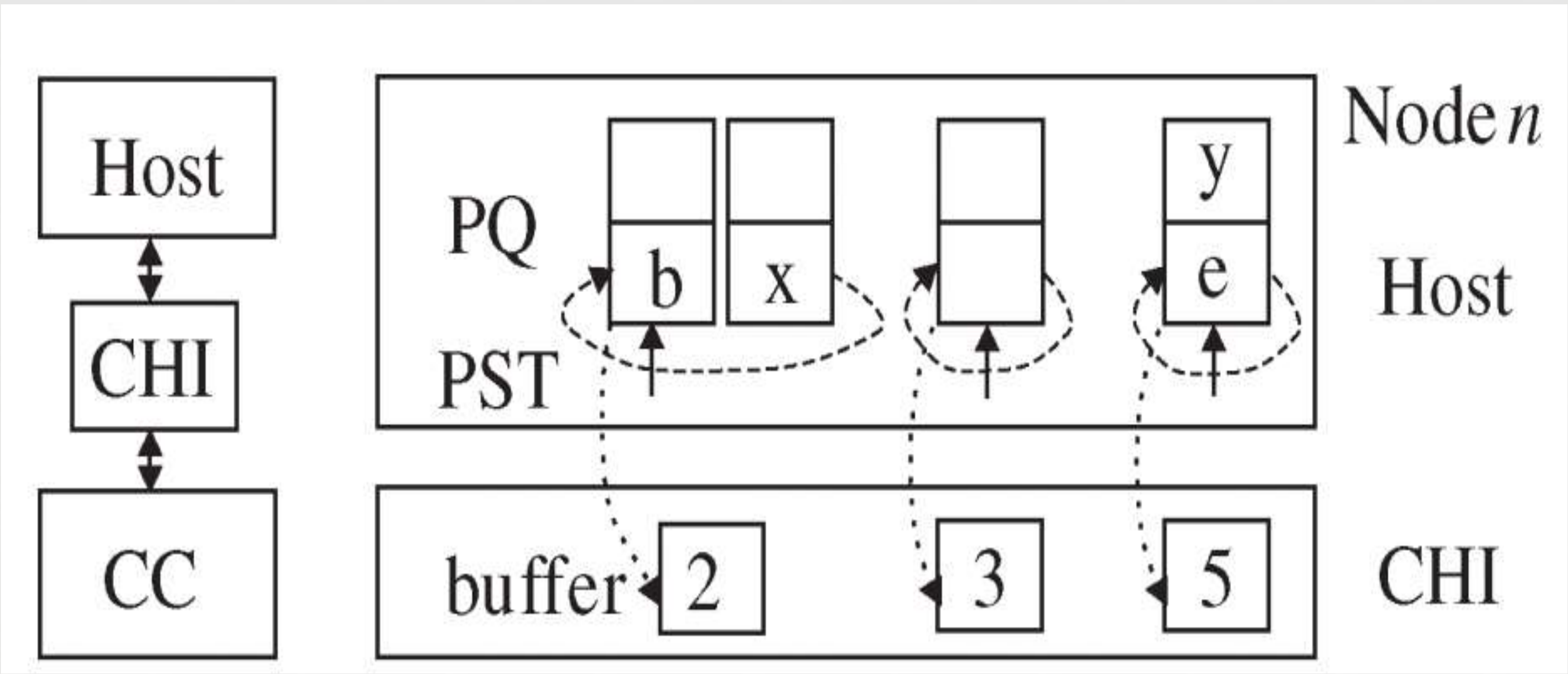

# Message Schedule For The DS

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- A reservation R for a node n is a 4-tuple (n,rp,w,l) with the reservation period rp $\in$ N, the offset w $\in$ {0,...,rp−1} and the reservation length l $\in$ N

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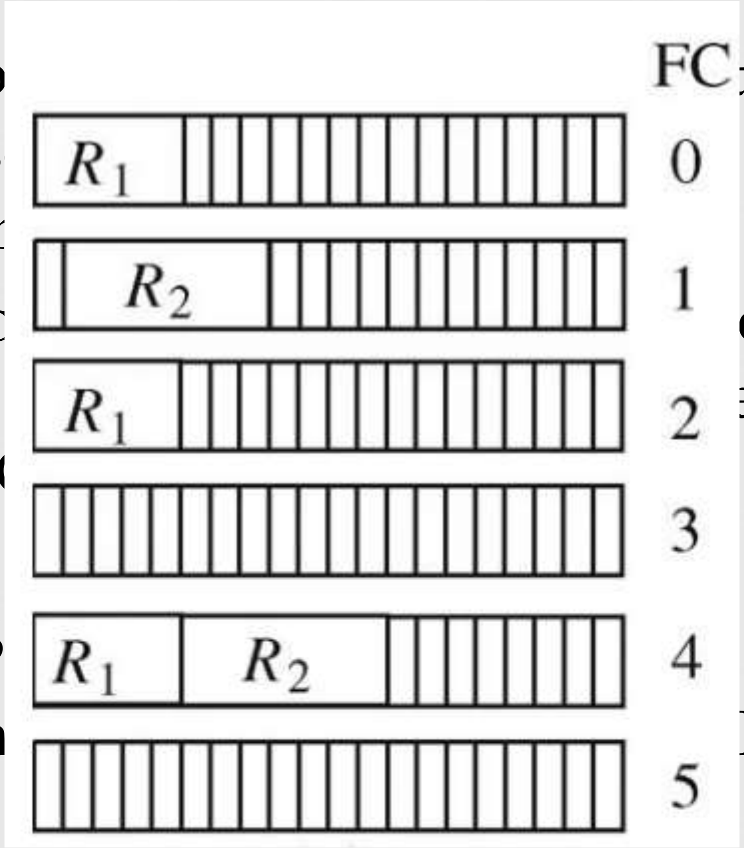

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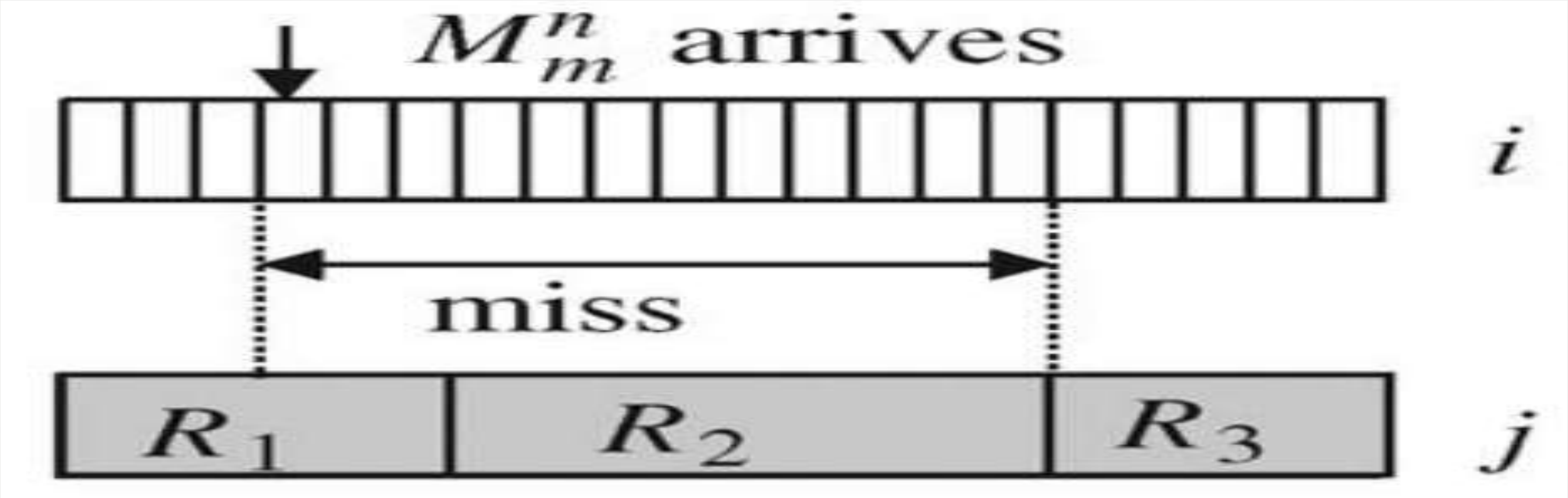
- If Tc is chosen larger than d, transmitting M multiple times in the same FC does not guarantee that M meets the deadline
- Hence, it must hold that $T_c \leq d_{min}$, where $d_{min}$ is the minimum deadline among all sporadic message deadlines.

# FC Time



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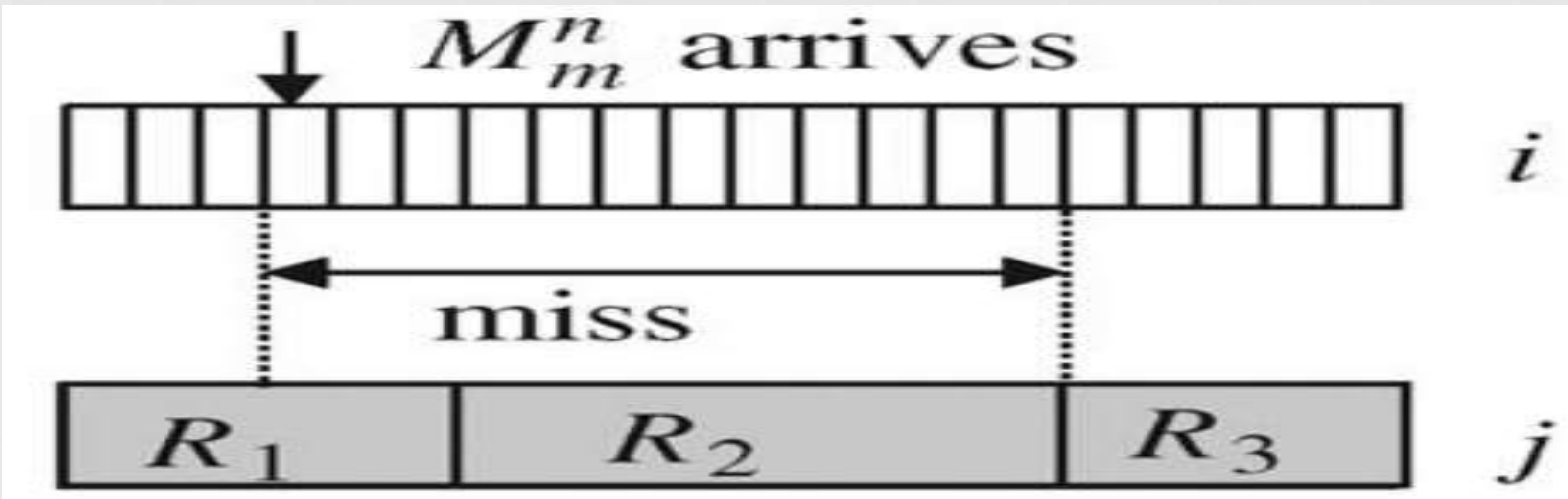


- Additionally (rp+1) * Tc ≤ dm and hence rp=dm/Tc−1

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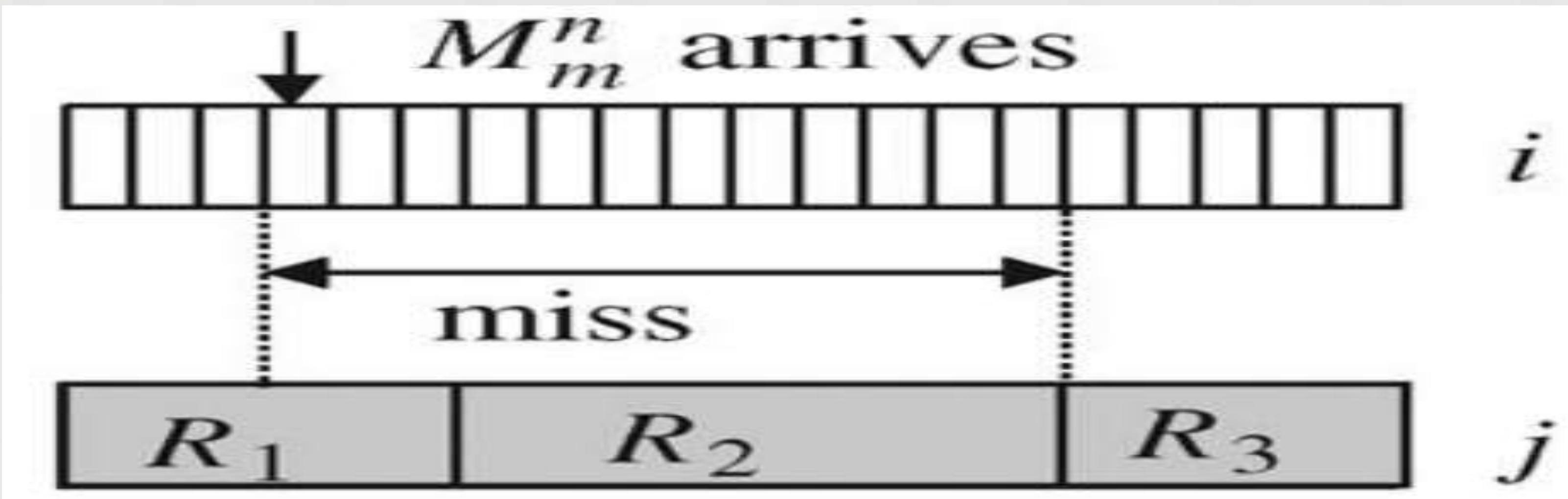


- Additionally (rp+1) * Tc ≤ dm and hence rp=dm/Tc−1
- Having determined the message reservation period for each message in MS, a good choice for the FC time Tc is the gcd of all rp

# Example Revisited

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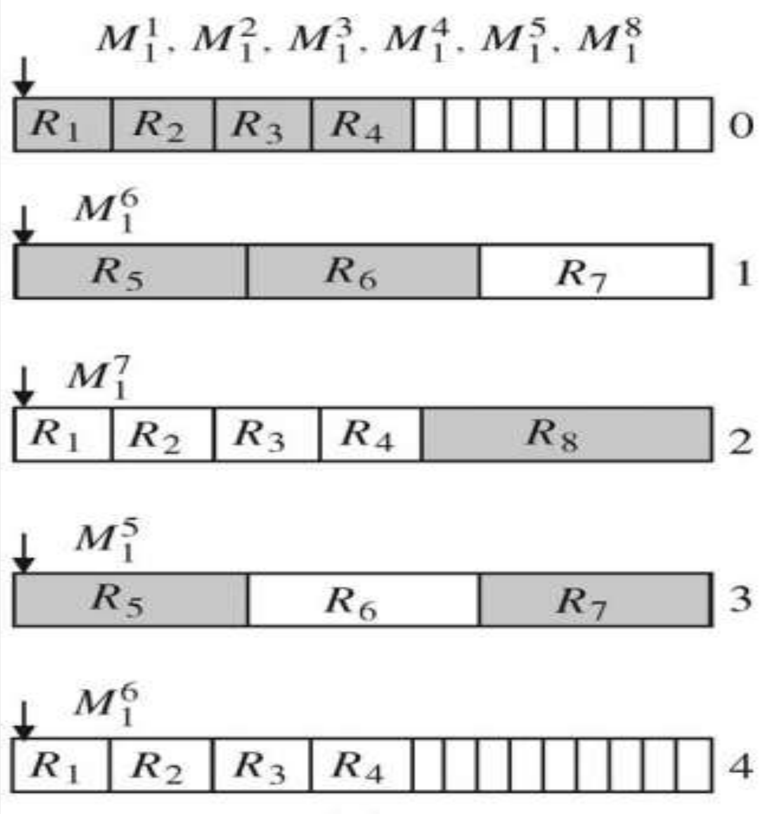

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- Cycle Load $L_j$ : The maximum number of MS that is reserved for message transmission in FC j for an arbitrary assignment of FIDs, considering that at most one FID can be assigned per message

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$$L_j = \sum_{R \in \mathcal{R}_j} l + \left( |\mathcal{M}_S| - \sum_{R \in \mathcal{R}_j} 1 \right) = \sum_{R \in \mathcal{R}_j} (l-1) + |\mathcal{M}_S|.$$

Where $j = (z \cdot rp + w)$

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then, we choose $N_{DS}=L_{max}$ and minimize $L_{max}$ to determine a feasible schedule with the shortest possible DS

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- Bandwidth Reservation: Indicate the number of MS reserved per FC for each node $n \in N$ and for all of the nodes

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$$B^n = \sum_{R \in R^n} (l/rp)$$

$$\sum_{n=1}^{N} B^n$$

# Message Grouping

**Algorithm 4.1 (Check and Add)**
Input: $M_l^n$, $\mathcal{G}_q^n$, $\mathcal{G}^n$.
Init: result $= more\_fit$
**if** ($P_{q,l}^n < 0$ or $RM_{q,l}^n < 1$)
  result $= no\_fit$
**else**
  $\mathcal{G}_q^n := \mathcal{G}_q^n \cup \{M_l^n\}$ and $\mathcal{G}^n = \mathcal{G}^n \cup \mathcal{G}_q^n$
  **if** ($RM_{q,l}^n = 1$)
    result $= last\_fit$
**return** result

# Message Grouping

**Algorithm 4.2 (Group)**

Input: $LM^n_{\mathrm{S}}, M^n_{\mathrm{c}}, \mathcal{G}^n_q, \mathcal{G}^n$

(**while** $M^n_{\mathrm{c}} < \mathbf{last}(LM^n_{\mathrm{S}})$)

  $M^n_{\mathrm{c}} = \mathbf{next}(M^n_{\mathrm{c}}))$

  $temp\mathcal{G}^n_q = \mathcal{G}^n_q$

  result $=$ $\mathbf{Check\ and\ Add}(M^n_{\mathrm{c}}, temp\mathcal{G}^n_q, \mathcal{G}^n)$

  **if** (result $= more\_fit$ and $M^n_{\mathrm{c}} \neq \mathbf{last}(LM^n_{\mathrm{S}})$)

    $tempM^n_{\mathrm{c}} = M^n_{\mathrm{c}}$

    **Group** $(LM^n_{\mathrm{S}}, tempM^n_{\mathrm{c}}, temp\mathcal{G}^n_q, \mathcal{G}^n)$

# Optimal Scheduling of Messages

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- Let N={1,2}. We assume that the groups in G have been computed as

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| | |
|---|---|
| $\mathcal{G}_1 = \{M_1^1\},\ pm_1^1 = 3,\ dm_1^1 = 5$<br>$R_1 = (1, 2, w_1, 20)$ | $\mathcal{G}_2 = \{M_1^1, M_2^1\},$<br>$R_2 = (1, 2, w_2, 30)$ |
| $\mathcal{G}_3 = \{M_2^1\},\ pm_2^1 = 5,\ dm_2^1 = 7$<br>$R_3 = (1, 4, w_3, 30)$ | $\mathcal{G}_4 = \{M_3^1\},\ pm_3^1 = 4, dm_3^1 = 6$<br>$R_4 = (1, 3, w_4, 10)$ |
| $\mathcal{G}_5 = \{M_1^2\},\ pm_1^2 = 3,\ dm_1^2 = 7$<br>$R_5 = (2, 2, w_5, 22)$ | $\mathcal{G}_6 = \{M_1^2, M_2^2\}$<br>$R_6 = (2, 2, w_6, 48)$ |
| $\mathcal{G}_7 = \{M_1^2, M_2^2, M_3^2\}$<br>$R_7 = (2, 2, w_7, 48)$ | $\mathcal{G}_8 = \{M_1^2, M_3^2\}$<br>$R_8 = (2, 2, w_8, 30)$ |
| $\mathcal{G}_9 = \{M_1^2, M_4^2\}$<br>$R_9 = (2, 2, w_9, 42)$ | $\mathcal{G}_{10} = \{M_2^2\}, pm_2^2 = 7, dm_2^2 = 9$<br>$R_{10} = (2, 6, w_{10}, 48)$ |
| $\mathcal{G}_{11} = \{M_3^2\}, pm_3^2 = 7, dm_3^2 = 9$<br>$R_{11} = (2, 6, w_{11}, 30)$ | $\mathcal{G}_{12} = \{M_4^2\}, pm_4^2 = 5, dm_4^2 = 5$<br>$R_{12} = (2, 4, w_{12}, 42)$ |

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# Optimal Scheduling of Messages

- Let N={1,2}. We assume that the groups in G have been computed as
- Our goal is now to determine $G_S$ and the offsets wi of the corresponding reservations such that Lmax(and, thus, the required duration $T_{DS}$ of the DS) is minimized

# Optimization Contd…

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- We formulate integer programming problems with two components to find the optimal message schedule
  - The first component addresses the selection of the message groups and the corresponding reservations. $gi \in \{0,1\}$ takes the value of 1 if $Gi \in G_S$ and is 0 otherwise
  - The second component is determining the reservation offsets. $x_{i,k} \in \{0,1\}$ takes the value of 1 if $w_i = k$ and is 0 otherwise, where $k=0,\ldots,rp_i-1$

# Optimization Contd…

Consider a reservation $R_i$ that corresponds to $\mathcal{G}_i \in \mathcal{G}$. The contribution of $R_i$ to $L_j$, $j = 1, \ldots, G_{\mathrm{RP}} - 1$, is given as follows.

1) $g_i = 0$: Then, $\mathcal{G}_i \notin \mathcal{G}^S$ and $R_i$ does not add to $L_j$.
2) $g_i = 1$ and $x_{i,k} = 1$ for $k = j \bmod rp_i$: Then, $w_i = k$ and $l_i$ MS are reserved for $R_i$ in $L_j$.
3) $g_i = 1$ and $x_{i,k} = 0$ for $k = j \bmod rp_i$: Then, $w_i \neq k$ and one MS is reserved for $R_i$ in $L_j$.

Accordingly, we can express the cycle load $L_j$ as follows:

$$L_j = \sum_{\mathcal{G}_i \in \mathcal{G}} g_i \cdot (x_{i,k} \cdot l_i + (1 - x_{i,k}) \cdot 1)$$

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- With the constraints

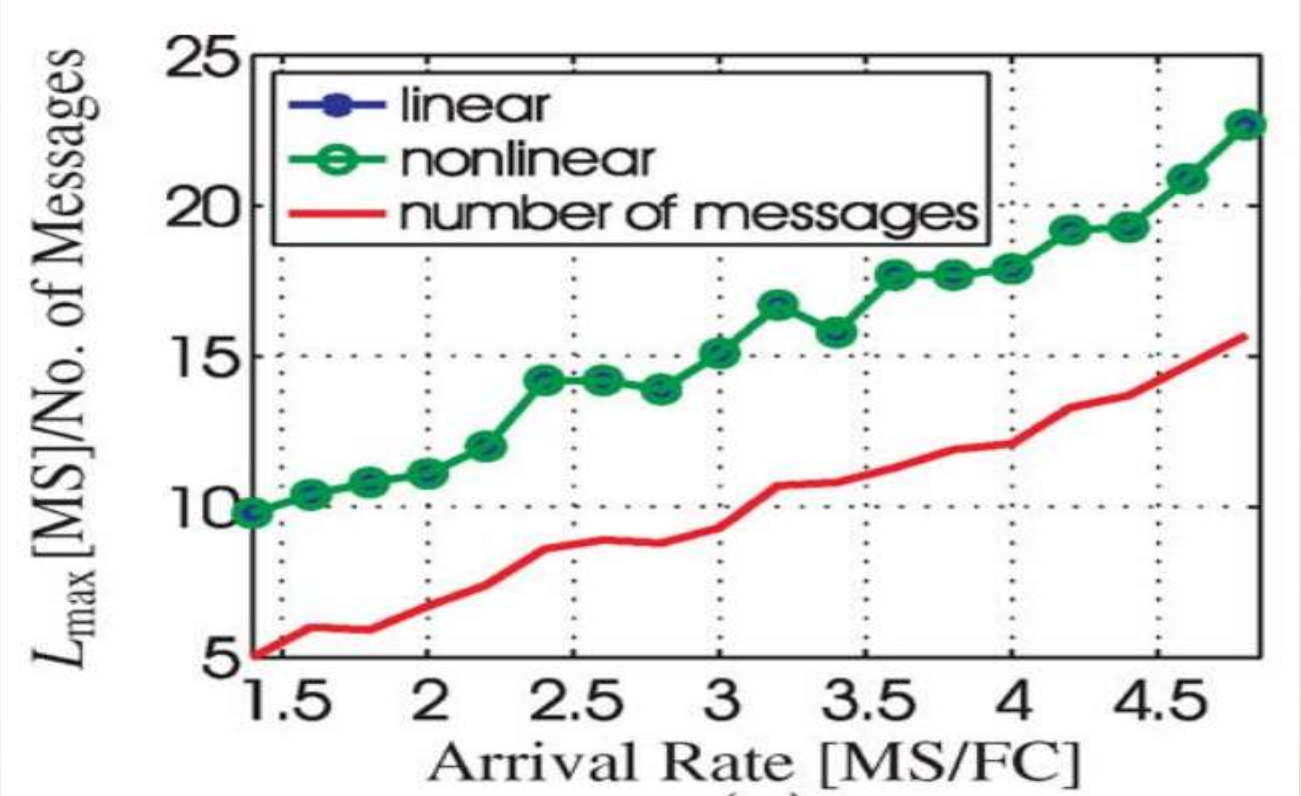
$$\forall M_m^n, \qquad \sum_{i, M_m^n \in \mathcal{G}_i} g_i = 1$$

$$\text{for } i = 1, \ldots, |\mathcal{G}|, \qquad \sum_{k=0}^{rp_i - 1} x_{i,k} = g_i$$

$$\text{for } j = 1, \ldots, G_{\mathrm{RP}} - 1, \qquad L_j \leq L_0.$$

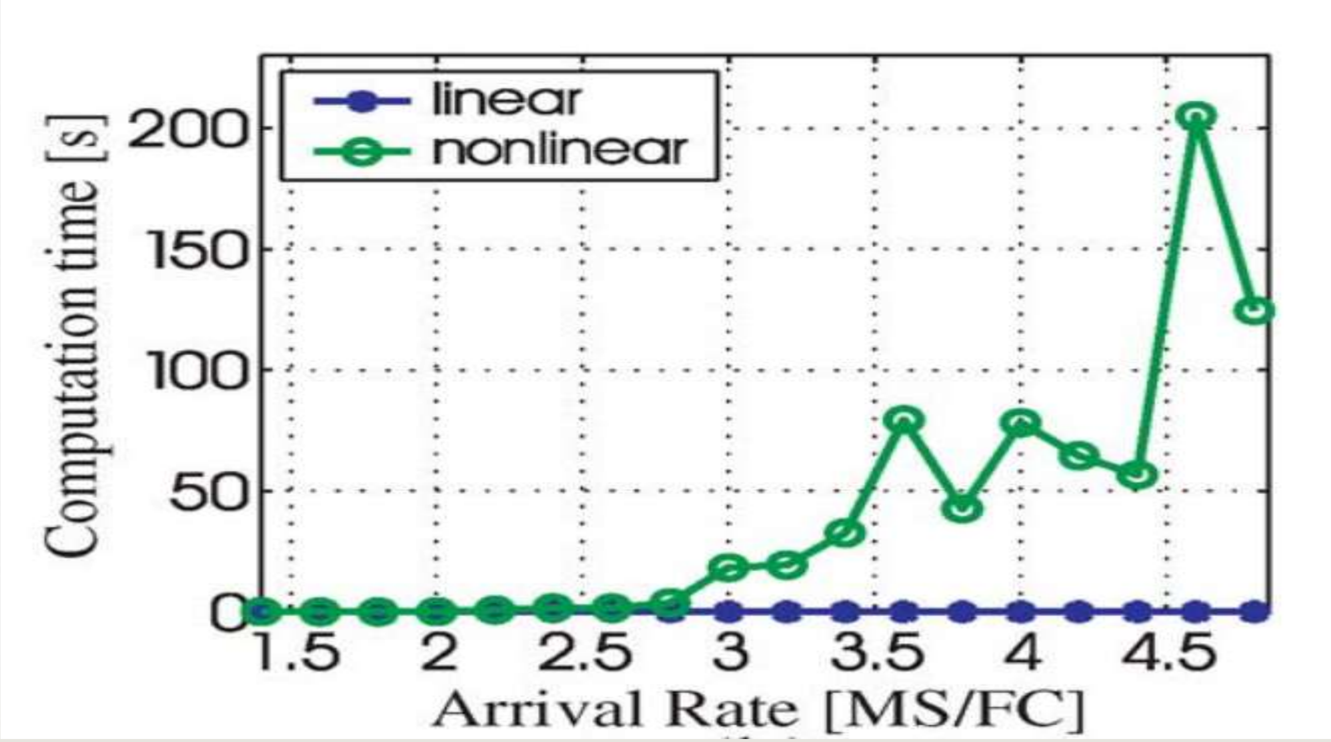
# Results

- Plot of the maximum cycle load Lmax, against the arrival rate



# Results

- Plot of the computational time, against the arrival rate



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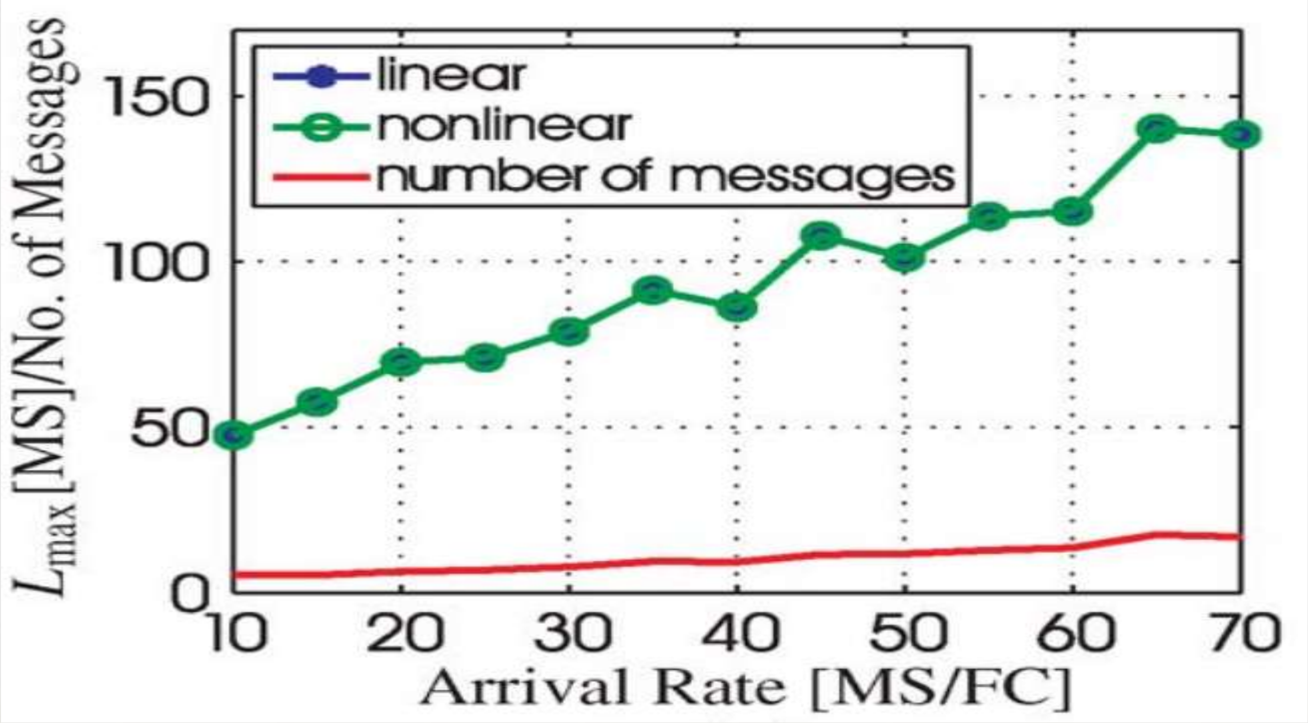
- Plot of the maximum cycle load Lmax, against the arrival rate(Extended Message Set)



# Results

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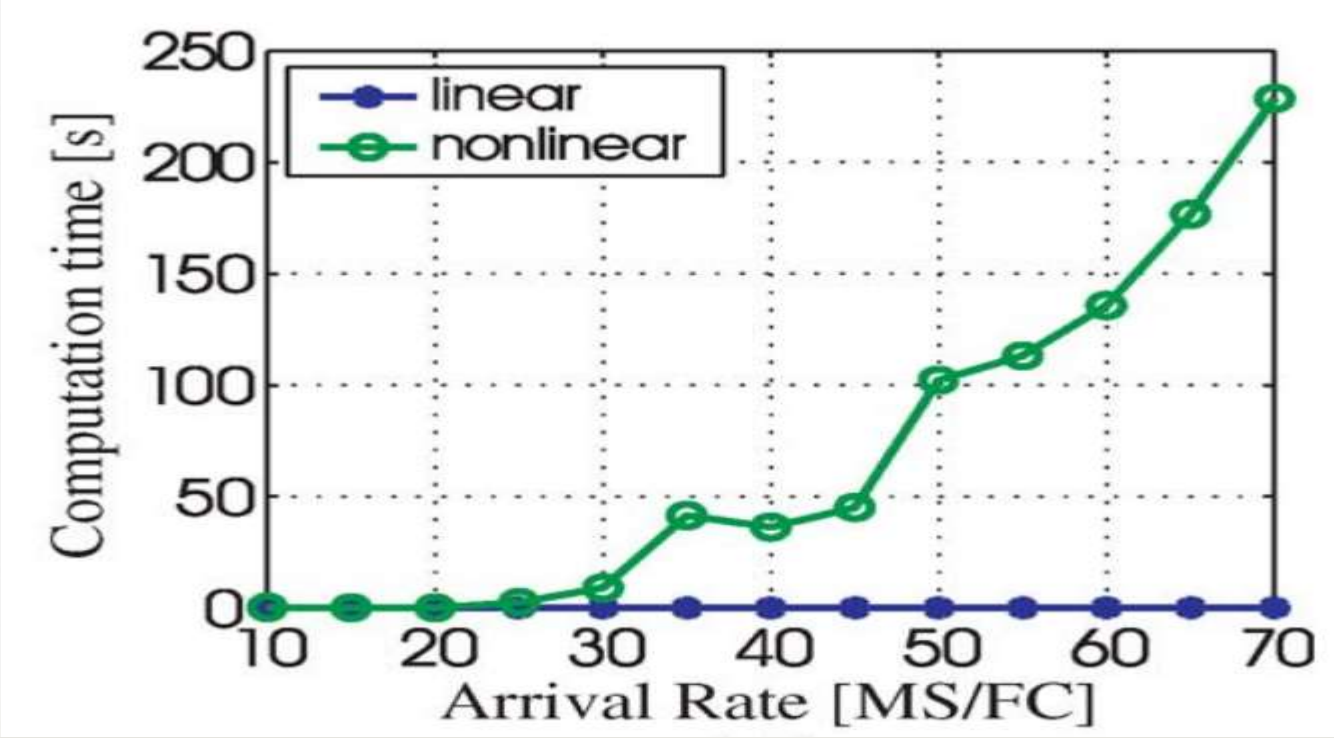

# Thank You