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Pushing The Limits of CAN

Scheduling Frames With Offsets Provides A Major Performance Boost

Presented By

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Presented By
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Outline

- Introduction
- Offset Assignment Algorithm
- Worst Case Response Times Results
- Offsets for Higher Network Loads
- Conclusion

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- In order to remain as a prominent automotive network, some enhancements in CAN are required to satisfy the future high bandwidth requirements.

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- This situation can be avoided by scheduling stream of messages with offsets
- The first instance of a stream of periodic frames is released with a delay, called the offset, relative to the first time at which the station is ready to transmit
- The challenge is to set the offsets in such a way as to minimize the WCRT

Offset Assignment Algorithm

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- Avoiding synchronous releases leading to traffic peaks and thus to large frame response times
- Tries to schedule the transmissions as far apart as possible
- The algorithm is executed on each station independently

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- The time is discrete with a certain granularity g
- A time instant that is a multiple of g is called a Possible Release Time i^{th} PRT occurs at time (i-1)*g

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  - T^i_k = Inter-Arrival Time Period
  - O^i_k = Offset: The duration between the first instant at which the station is operational and the transmission of the first frame of stream f^i_k

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- Lets look at an example

Analysis Duration

$f_1 = (T_1 = 10, O_1 = 4)$, $f_2 = (20, 8)$ and $f_3 = (20, 18)$ $(T_{\max} = 20)$ with a granularity $g = 2$.

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possible release time i	1	2	3	4	5	6	7	8	9	10
$R[i]$ (frames released)			$f_{1,1}$		$f_{2,1}$			$f_{1,2}$		$f_{3,1}$

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possible release time i	1	2	3	4	5
possible release times adjacent to i	{5,2}	{1,3}	{2,4}	{3,5}	{4,1}

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  C. Set the offset O_k in the middle of the selected interval, the corresponding possible release time is r_k
  D. Update the release array R to store the frames of f_k released in the interval $[0, T_{max}]$

$$\forall i \in \mathbb{N} \text{ and } r_k + i \cdot \frac{T_k}{g} \leq \frac{T_{\max}}{g}$$

$$\text{do } R\left[r_k + i \cdot \frac{T_k}{g}\right] = R\left[r_k + i \cdot \frac{T_k}{g}\right] \cup f_{k,i+1}$$

Example

$f_1 = (T_1 = 10, O_1 = 4)$, $f_2 = (20, 8)$, $f_3 = (20, 18)$ and a time granularity equal to 2. First the algorithm decides the offset for f_1: $l_1 = 0$ (step $1.(a)$), $B_1 = 1$ and $E_1 = 5$ (step $1.(b)$), thus $r_1 = 3$ (step $1.(c)$), which means that the offset of the stream is 4. Then array R is updated: $R[3] = \{f_{1,1}\}$ and $R[8] = \{f_{1,2}\}$ (step $1.(d)$). For stream f_2: $l_2 = 0$, the selected interval is $\{4, 5, 6, 7\}$ thus $B_2 = 4$, $E_2 = 7$ and $r_2 = 5$ with $R[5] = \{f_{2,1}\}$. For stream f_3, $l_3 = 0$, the selected interval is $\{9, 10, 1, 2\}$ thus $B_3 = 9$, $E_3 = 2$ and $r_3 = 10$ with $R[10] = \{f_{3,1}\}$.

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$f_1 = (T_1 = 10, O_1 = 4)$, $f_2 = (20, 8)$ and $f_3 = (20, 18)$ $(T_{\max} = 20)$ with a granularity $g = 2$.

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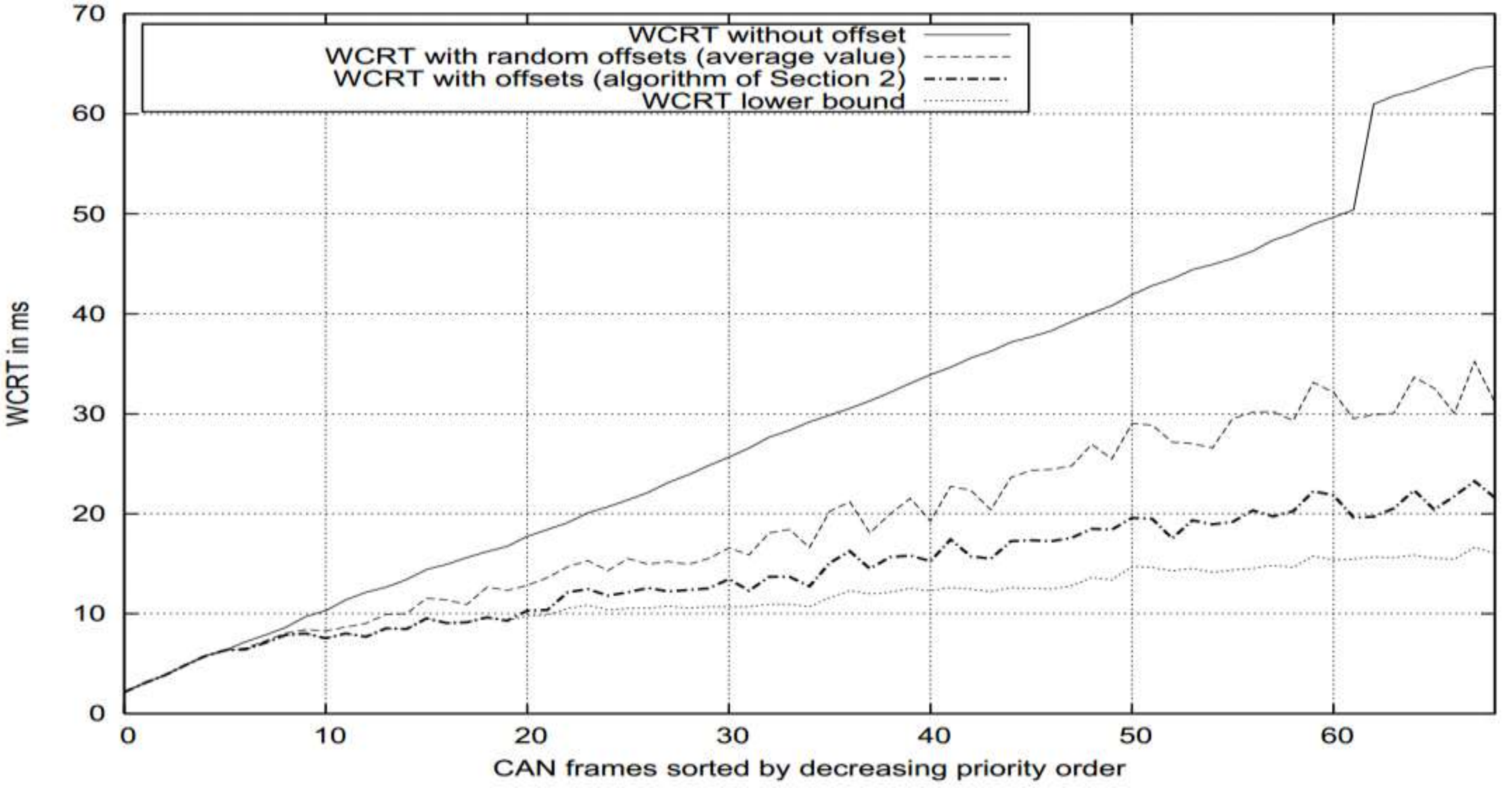
- Offsets results in the reduction of the WCRT for low priority messages

Worst Case Response Times Results



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Worst Case Response Times Results

- Offsets results in the reduction of the WCRT for low priority messages
- For the lowest priority frame of this example, the WCRT with offsets is decreased by 43.2 ms (from 64.8 to 21.6)

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- The performance metric is the ratio of WCRT reduction when using offsets with the algorithm described

WCRT Reduction Ratio
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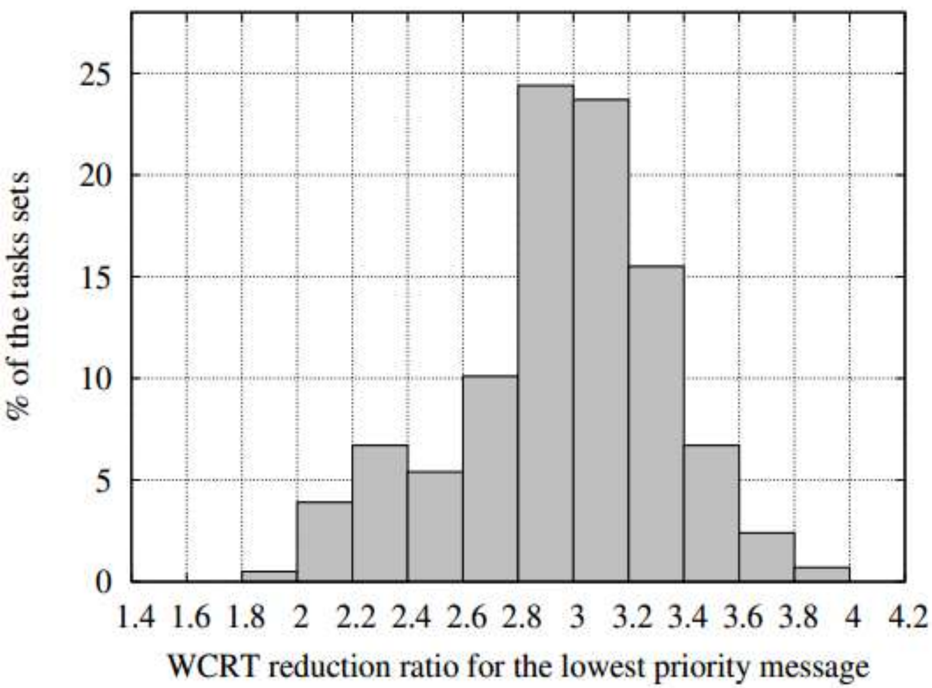
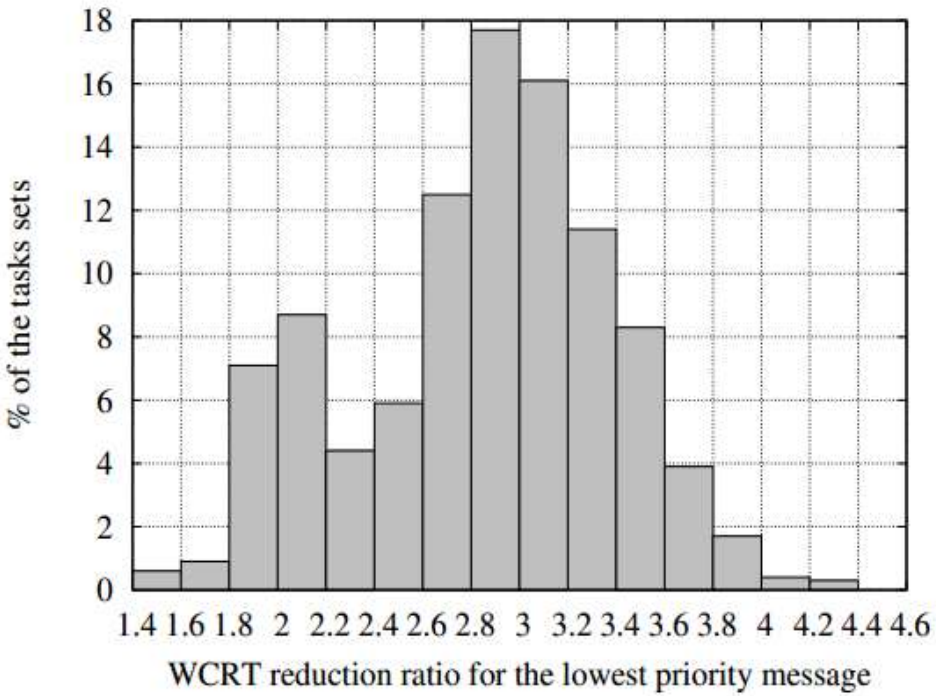
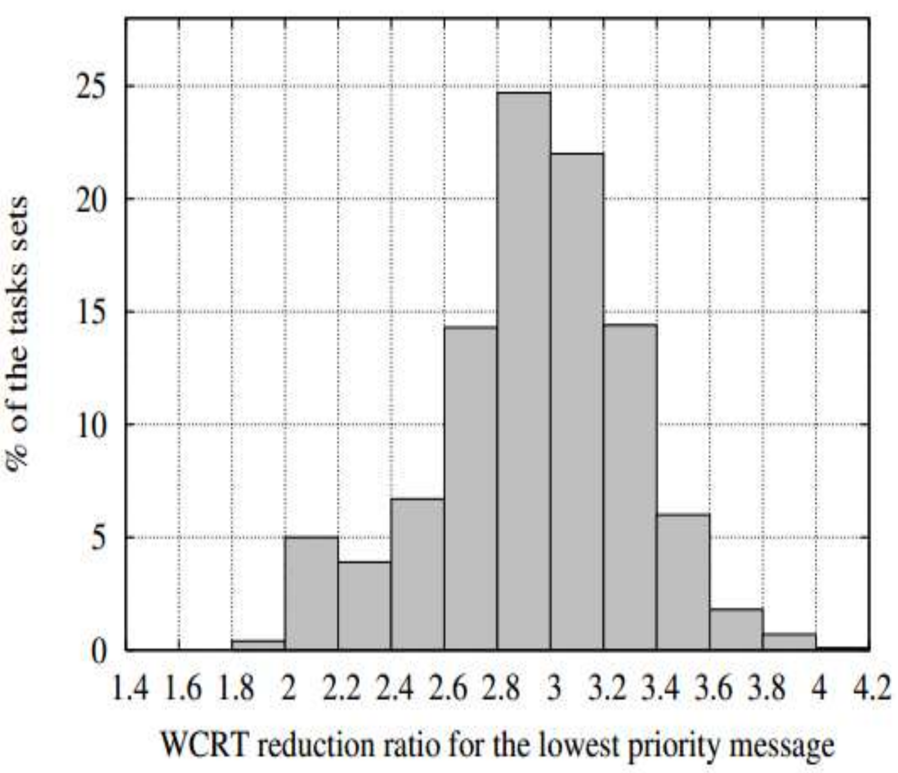


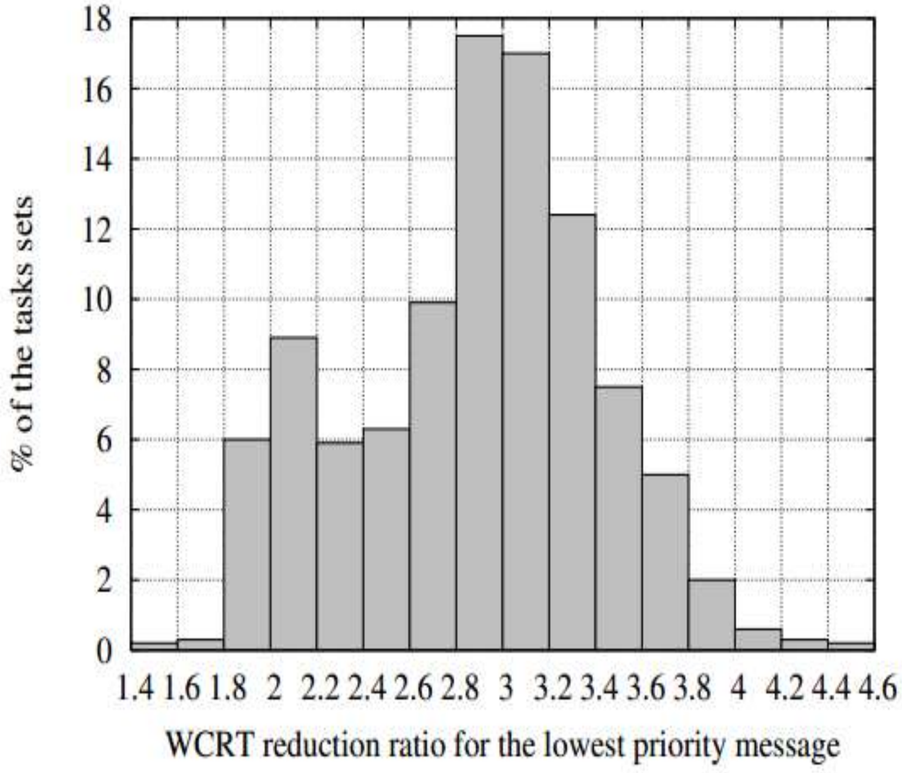
Body Network



Chassis Network

WCRT Reduction Ratio (30% Concentration)





Network Load Distribution

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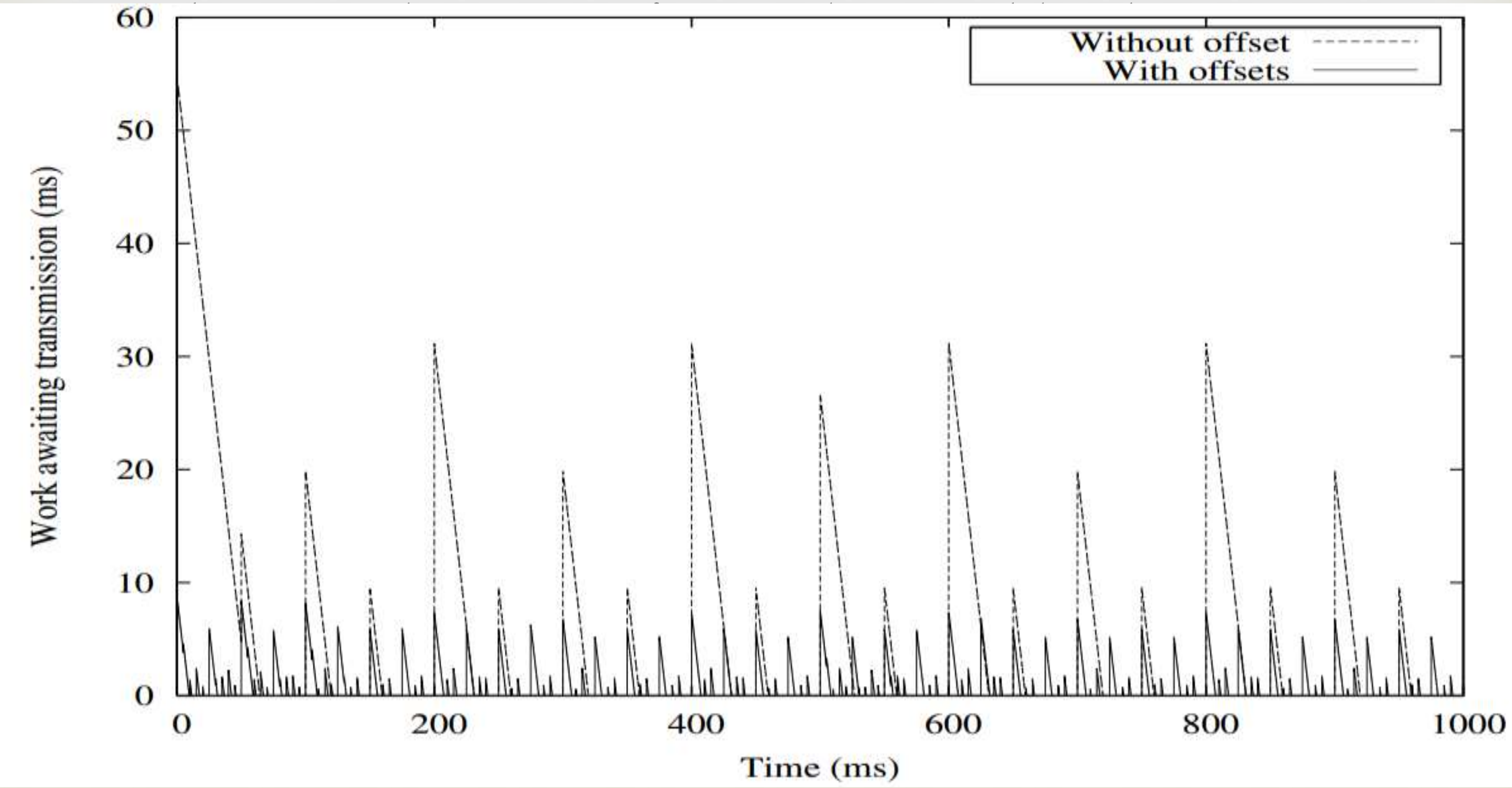
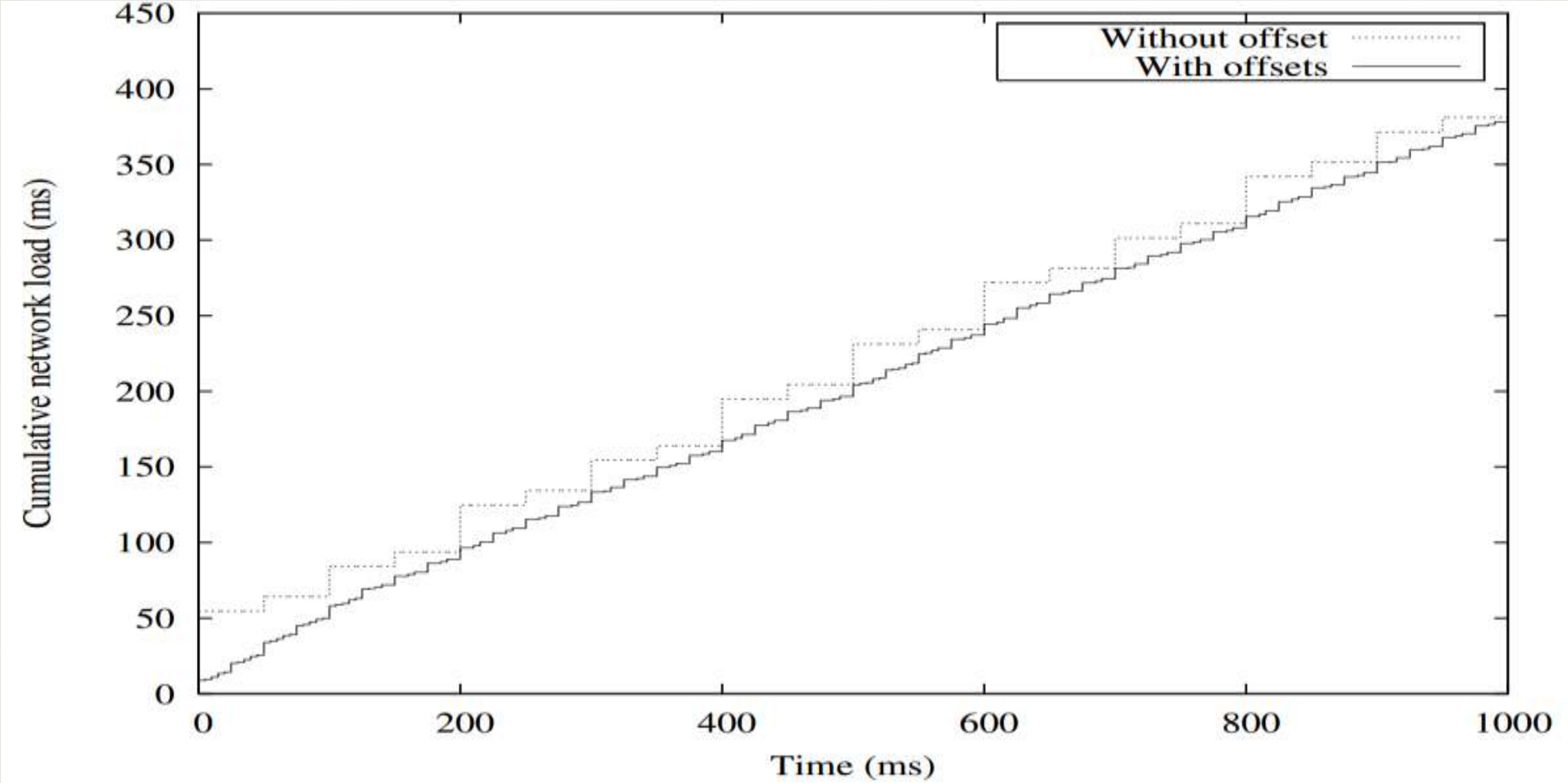
- The evolution of total workload awaiting transmission is measured during one second with and without offsets

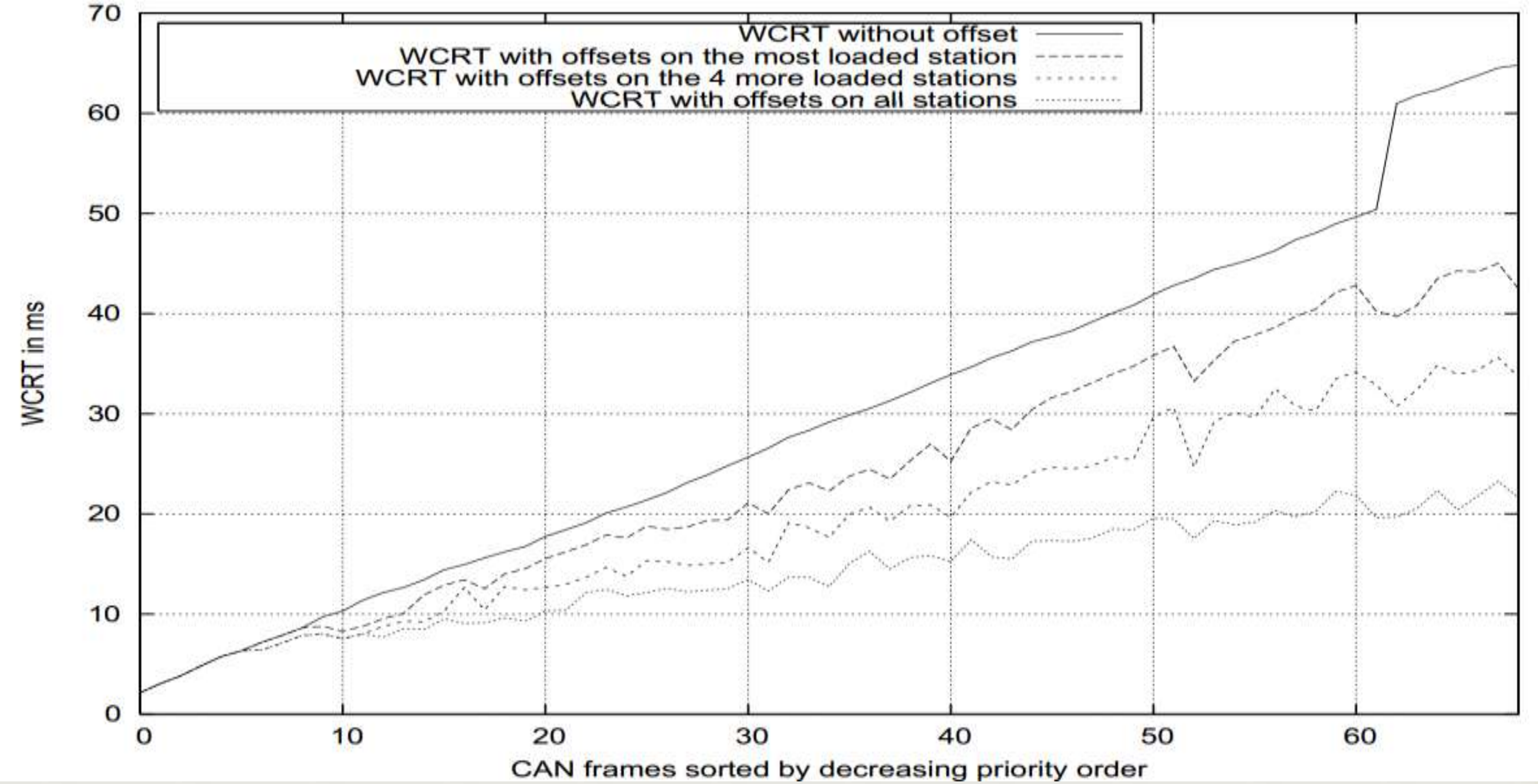
Network Load Distribution



Cumulative Network Load



Partial Offset Usage



Offsets and Load

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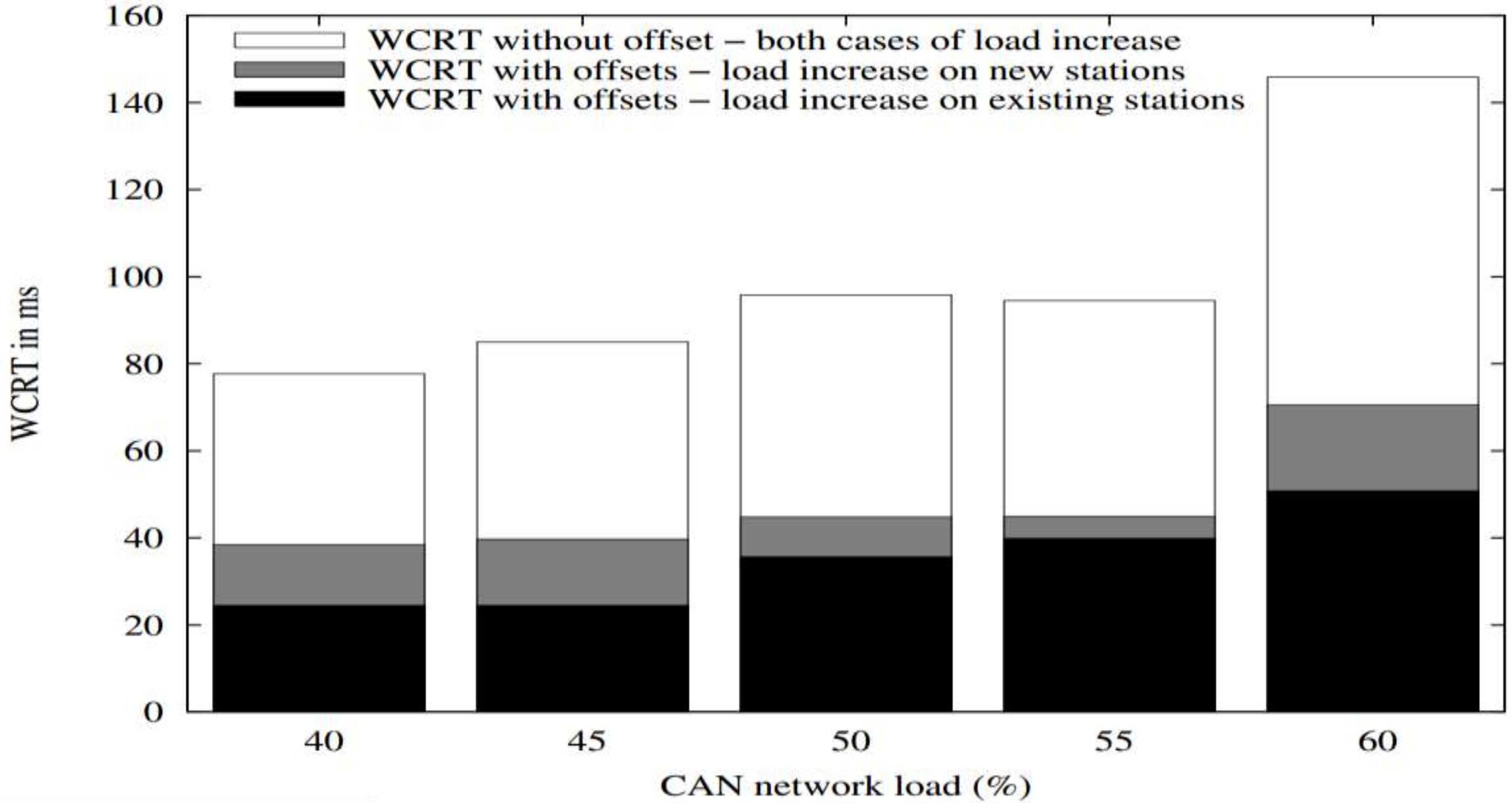
- Load can be increased either adding more stations or messages

Offsets and Load



Conclusion

- A low-complexity algorithm for deciding offsets, which has good performances for typical automotive networks
- Using offsets is a robust technique that might actually provide a solution in the short term to deal with the increasing network load
- Offsets, which impose constraints on the frame release dates, can be seen as a trade-off between event-triggered communications and time-triggered communications