Bounding and Shaping the Demand of Mixed-Criticality Sporadic Tasks

Pontus Ekberg & Wang Yi

Uppsala University, Sweden

ECRTS 2012

Mixed-criticality sporadic tasks

Task τ_i

$C_i(\text{LO})$: WCET at low-criticality

$C_i(\text{HI})$: WCET at high-criticality

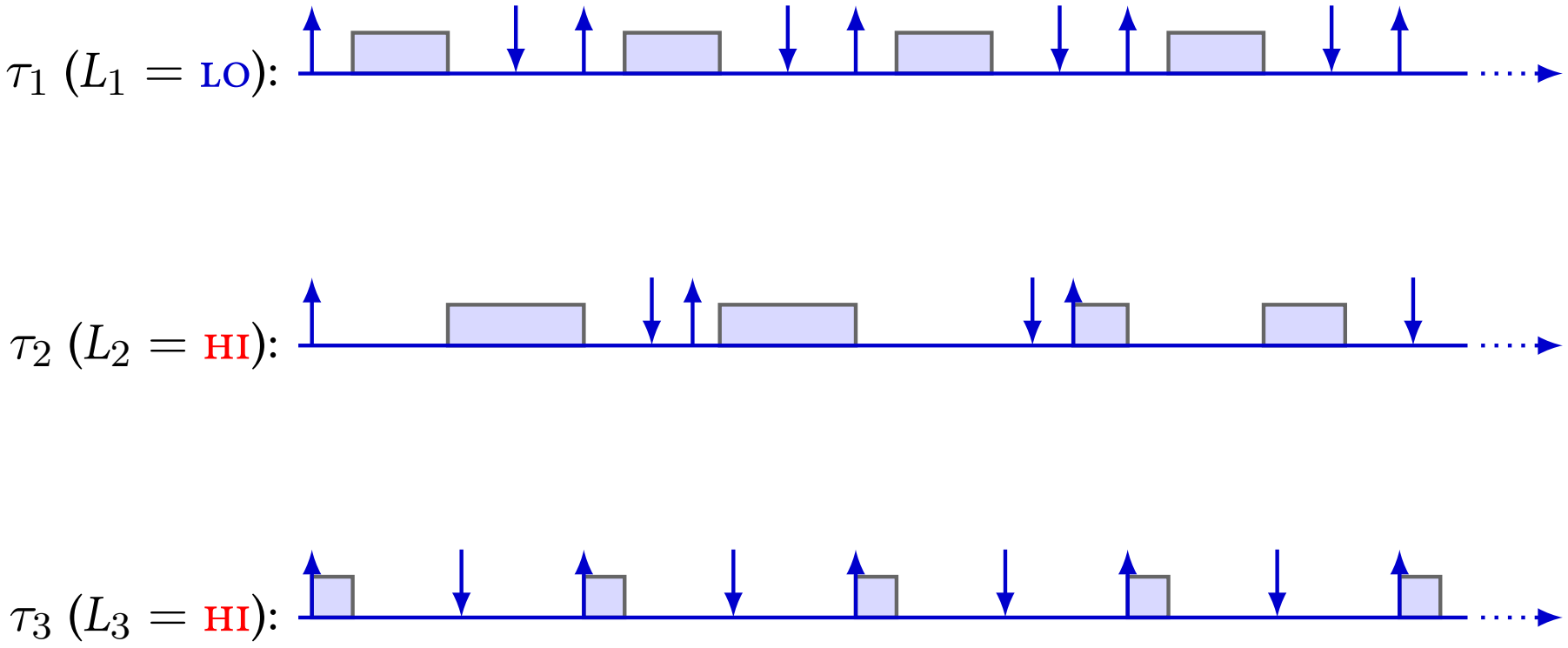
D_i: Relative deadline

T_i: Period

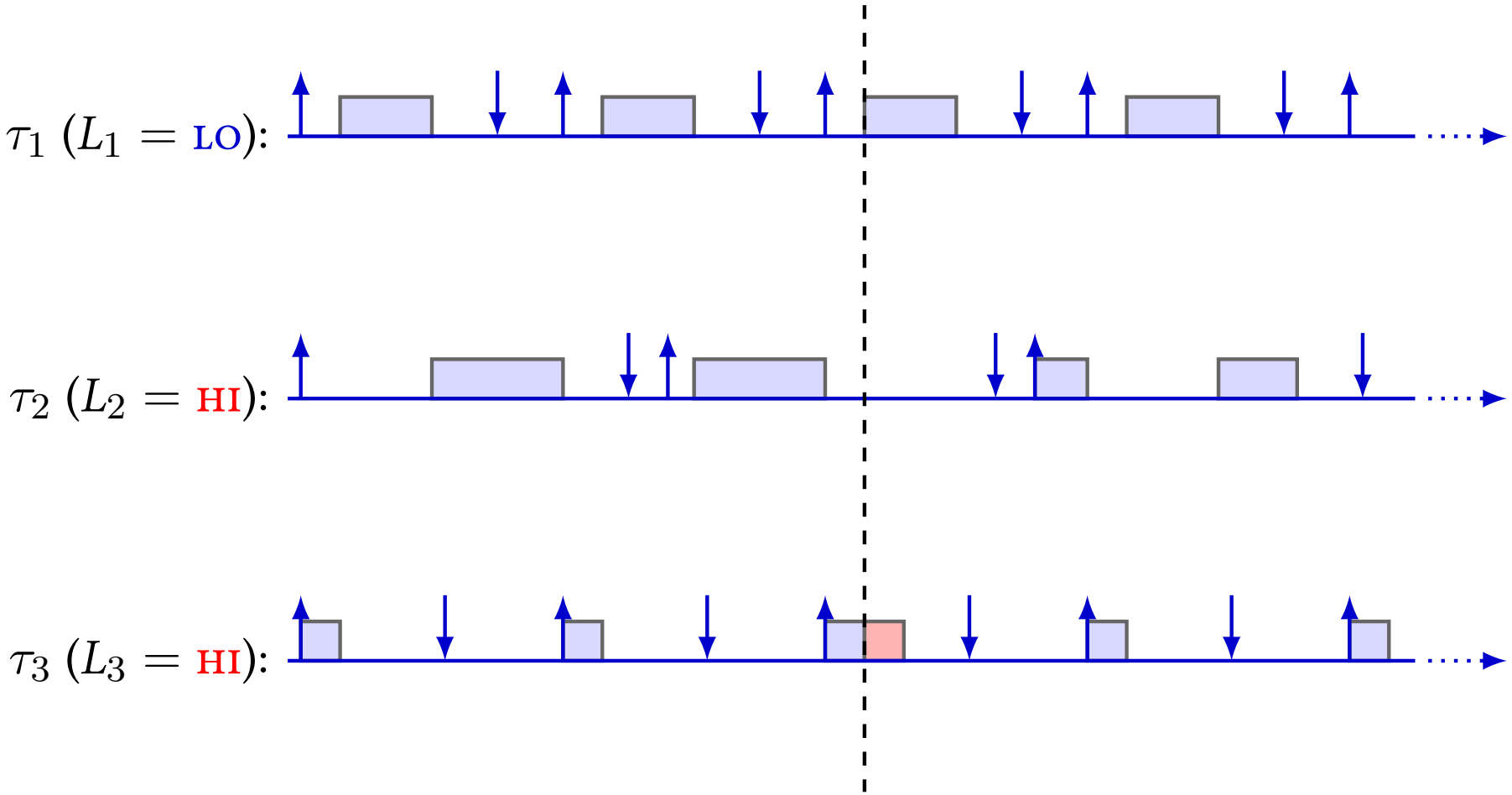
L_i: Criticality (LO or HI)

$(C_i(\text{LO}) \leqslant C_i(\text{HI}))$

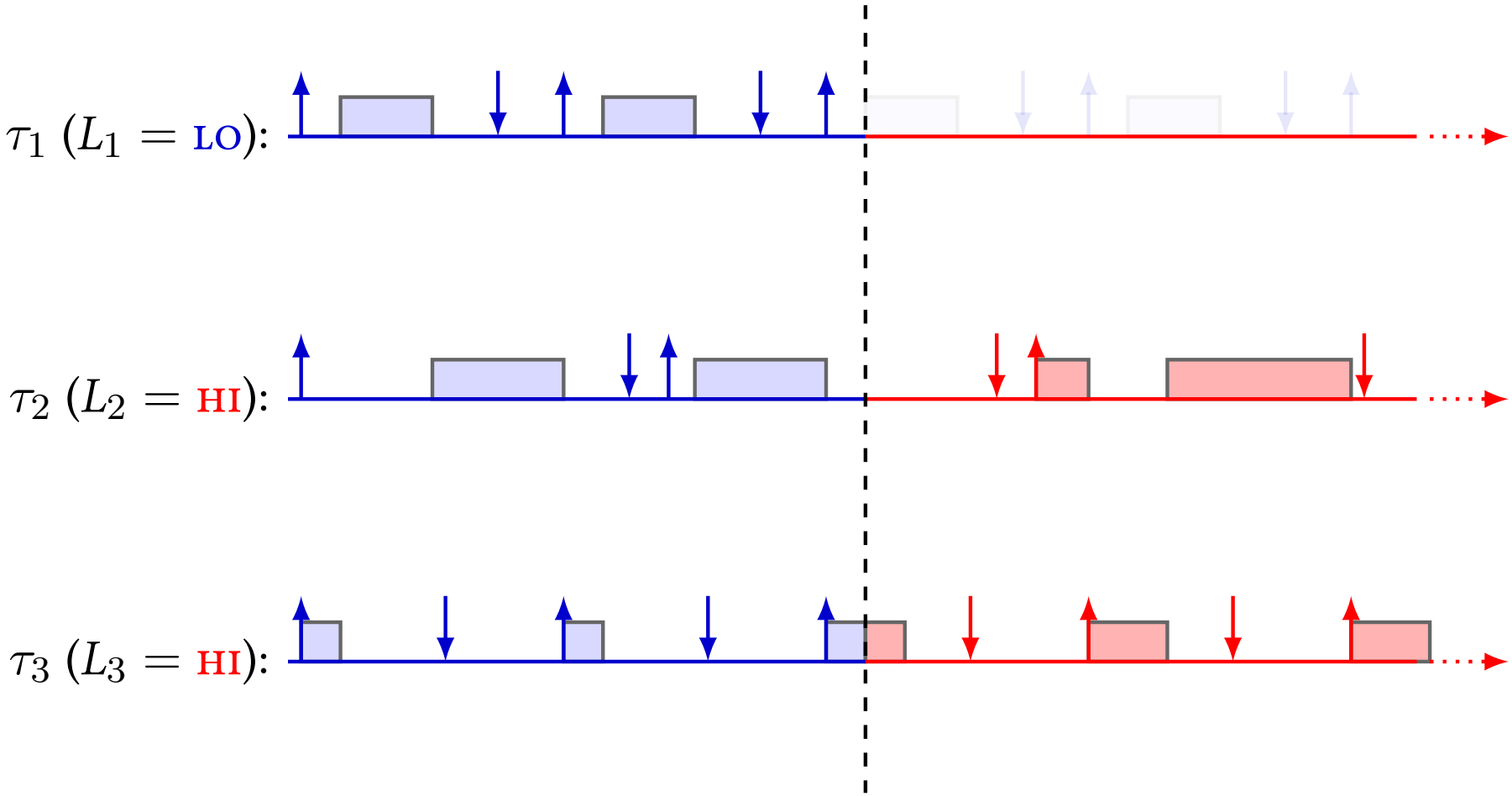
Mixed-criticality sporadic tasks



Mixed-criticality sporadic tasks



Mixed-criticality sporadic tasks

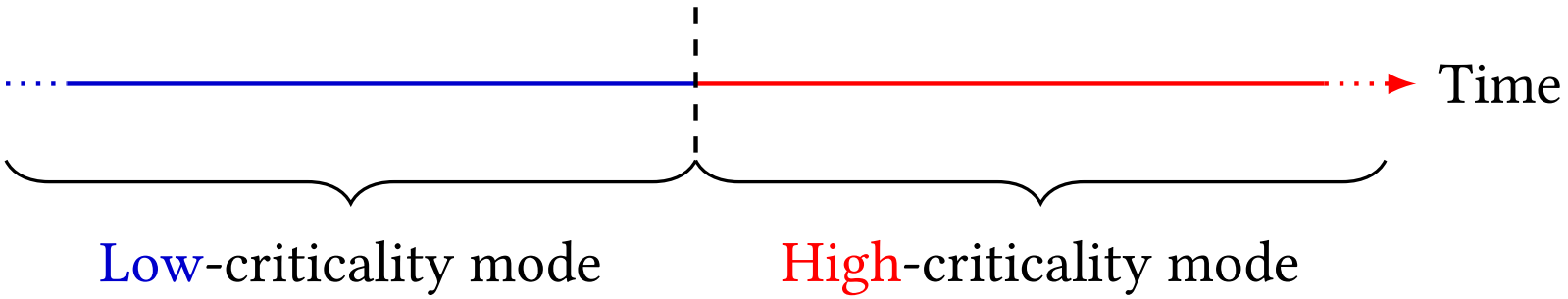


Schedulability analysis

Classic EDF analysis

A task set τ is schedulable if

$$\forall \ell \geqslant 0 : \quad \sum_{\tau_i \in \tau} \mathrm{dbf}(\tau_i, \ell) \leqslant \mathrm{sbf}(\ell).$$



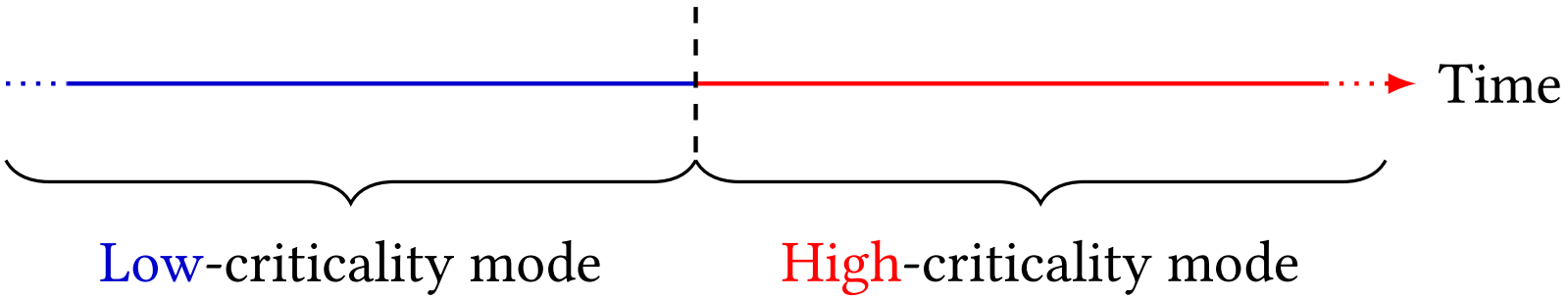
Schedulability analysis

Mixed-criticality EDF analysis

A task set τ is schedulable if both **A** and **B** hold:

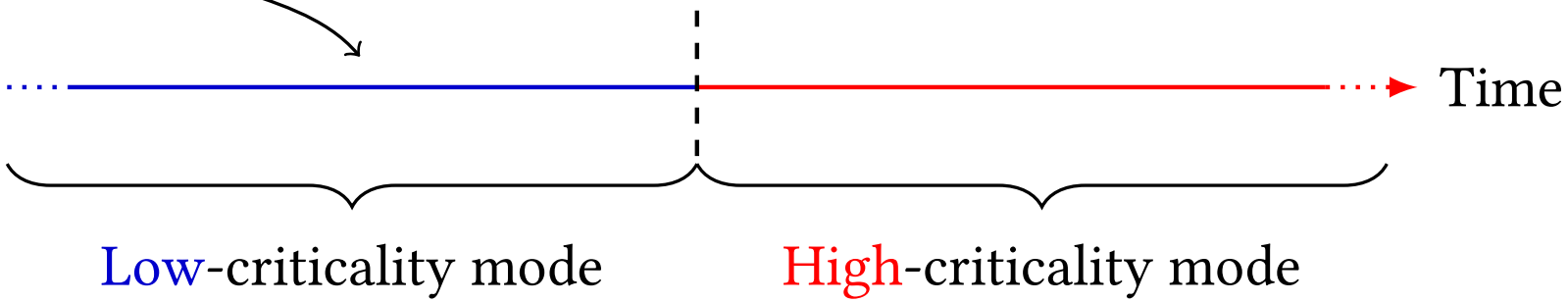
$$\mathbf{A}: \qquad \forall \ell \geqslant 0: \quad \sum_{\tau_i \in \tau} \mathrm{dbf}_{\mathrm{LO}}(\tau_i, \ell) \leqslant \mathrm{sbf}_{\mathrm{LO}}(\ell)$$

$$\mathbf{B}: \qquad \forall \ell \geqslant 0: \quad \sum_{\tau_i \in \mathrm{HI}(\tau)} \mathrm{dbf}_{\mathrm{HI}}(\tau_i, \ell) \leqslant \mathrm{sbf}_{\mathrm{HI}}(\ell)$$



Demand-bound functions

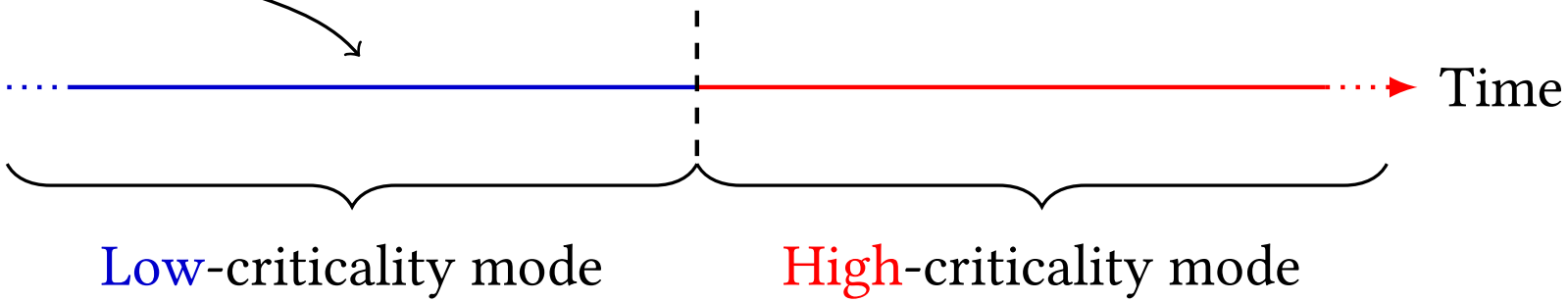
Each τ_i behaves exactly like a standard sporadic task with WCET $C_i(\text{LO})$.



Demand-bound functions

Use dbf*s from Baruah et al., 1990!*

Each τ_i behaves exactly like a standard sporadic task with WCET $C_i(\text{LO})$.

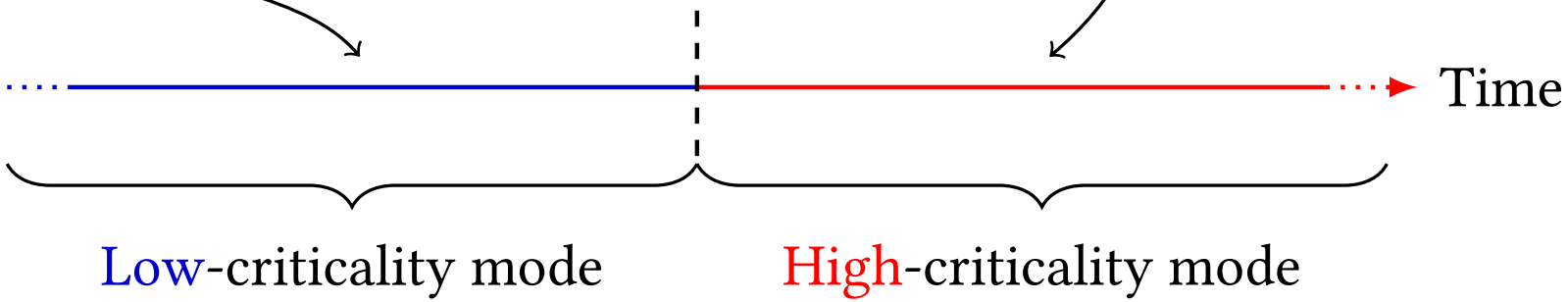


Demand-bound functions

Each τ_i behaves *similar to* a standard sporadic task with WCET $C_i(\text{HI})$.

Use dbfs *from Baruah et al., 1990!*

Each τ_i behaves exactly like a standard sporadic task with WCET $C_i(\text{LO})$.

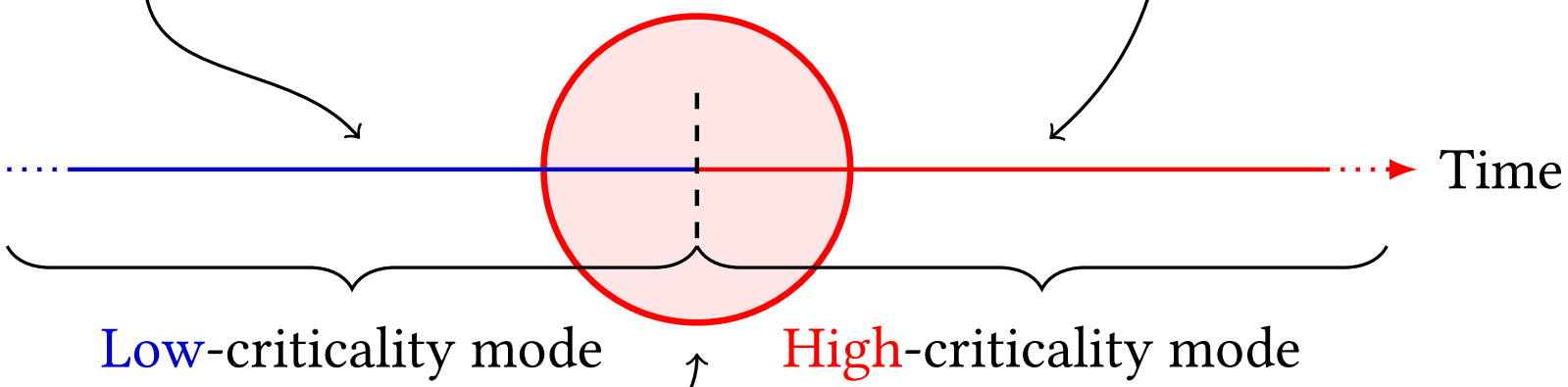


Demand-bound functions

Each τ_i behaves *similar to* a standard sporadic task with WCET $C_i(\text{HI})$.

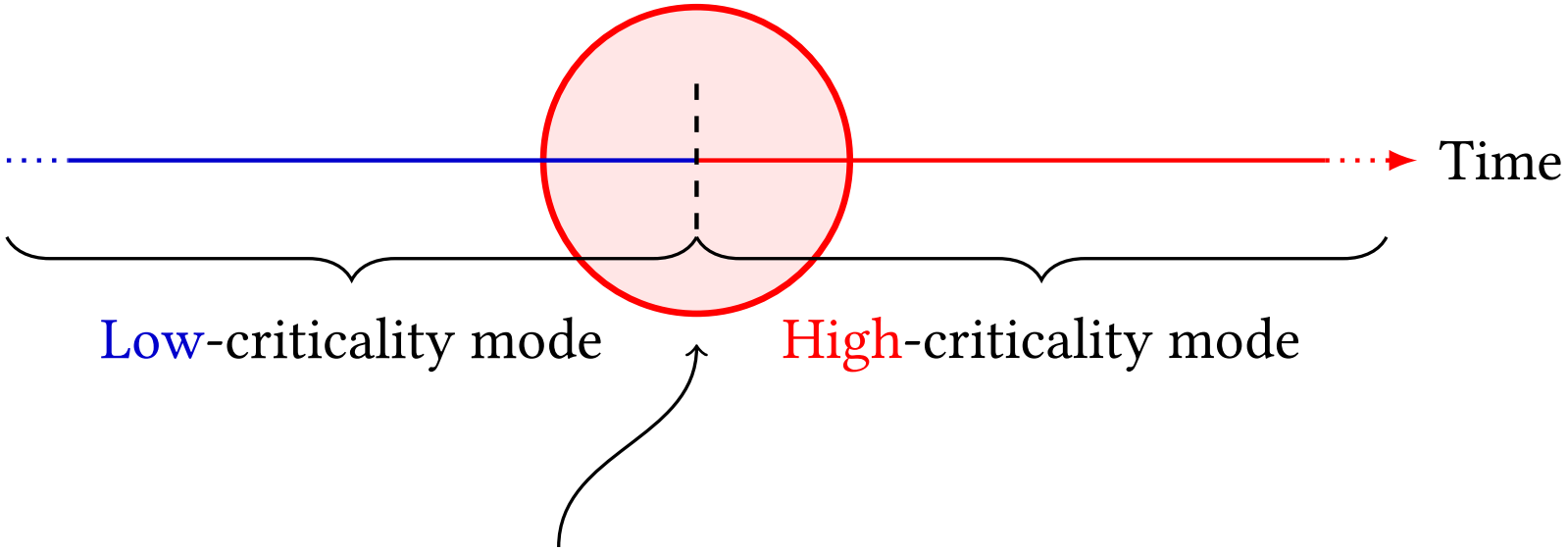
Use dbfs *from Baruah et al., 1990!*

Each τ_i behaves exactly like a standard sporadic task with WCET $C_i(\text{LO})$.



Half-finished jobs are carried over to high-criticality mode.

Carry-over jobs

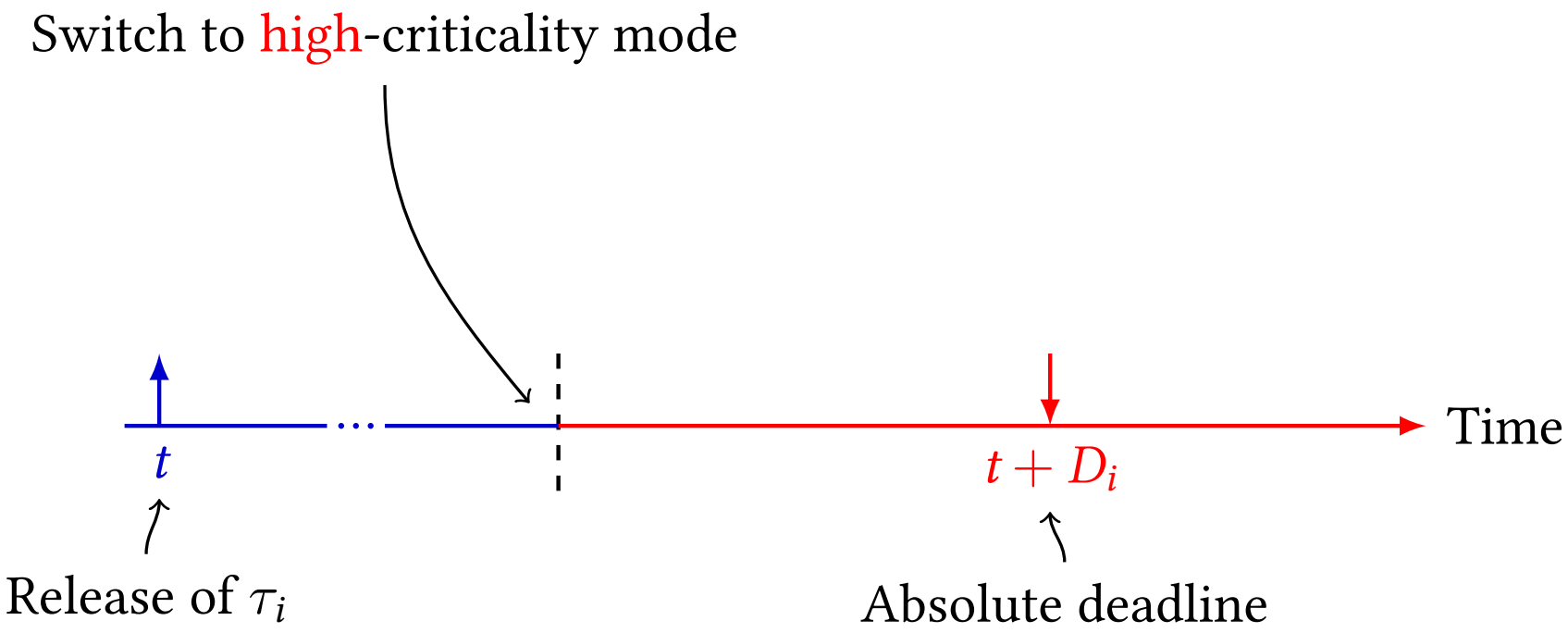


Half-finished jobs are carried over to high-criticality mode.

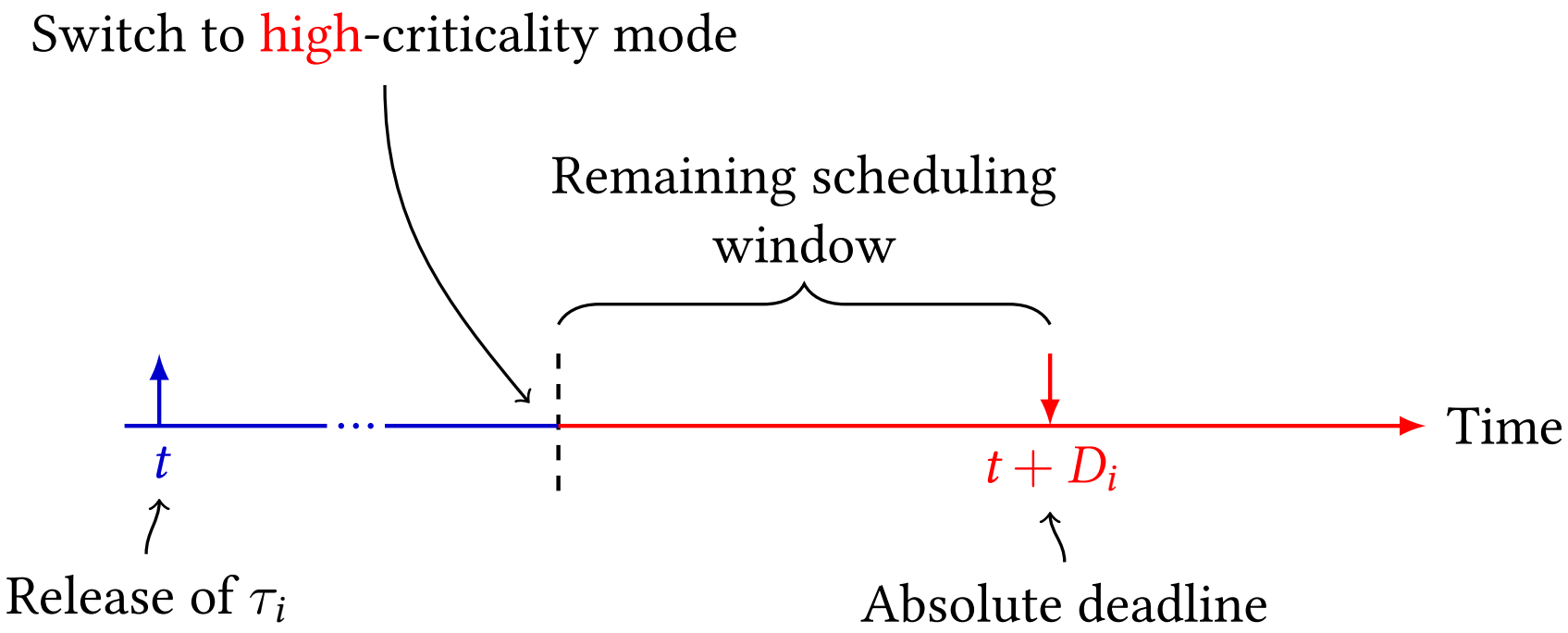
Restricting to the interesting cases

To show $\mathbf{A} \wedge \mathbf{B}$, we show $\mathbf{A} \wedge (\mathbf{A} \rightarrow \mathbf{B})$.

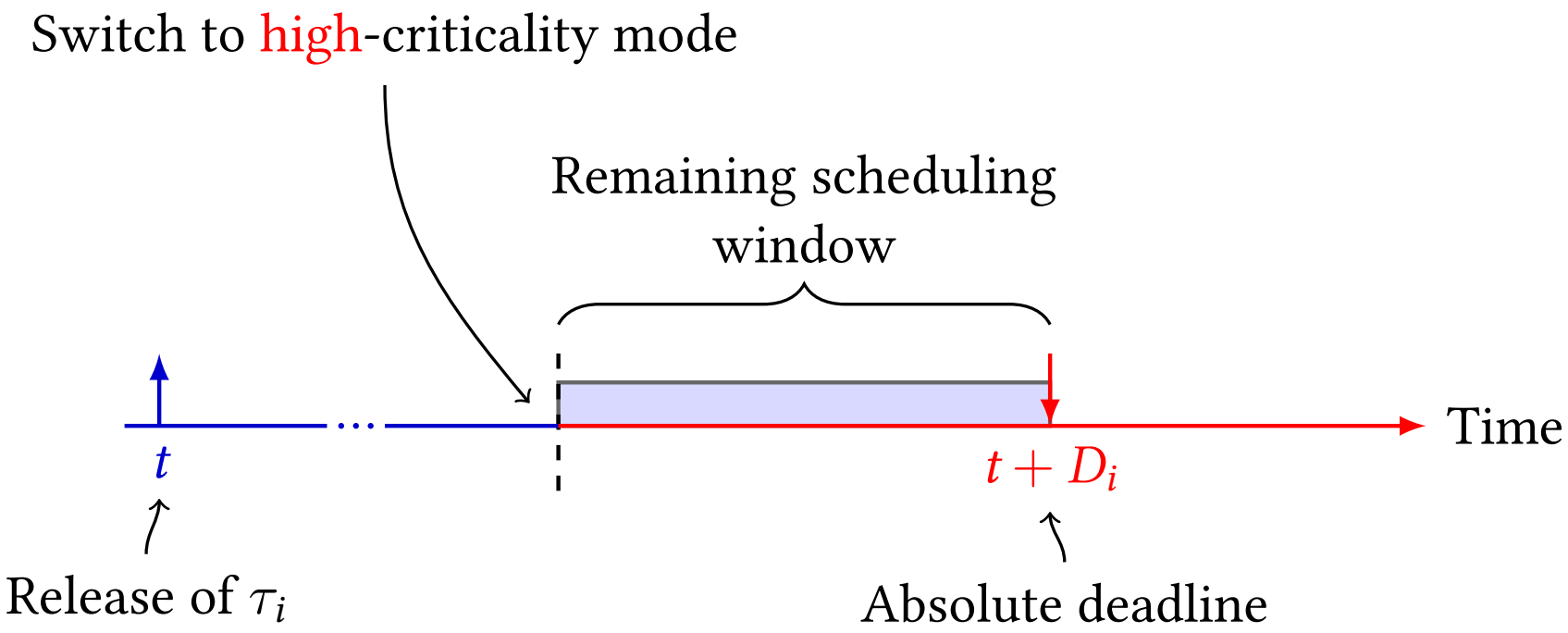
Carry-over jobs



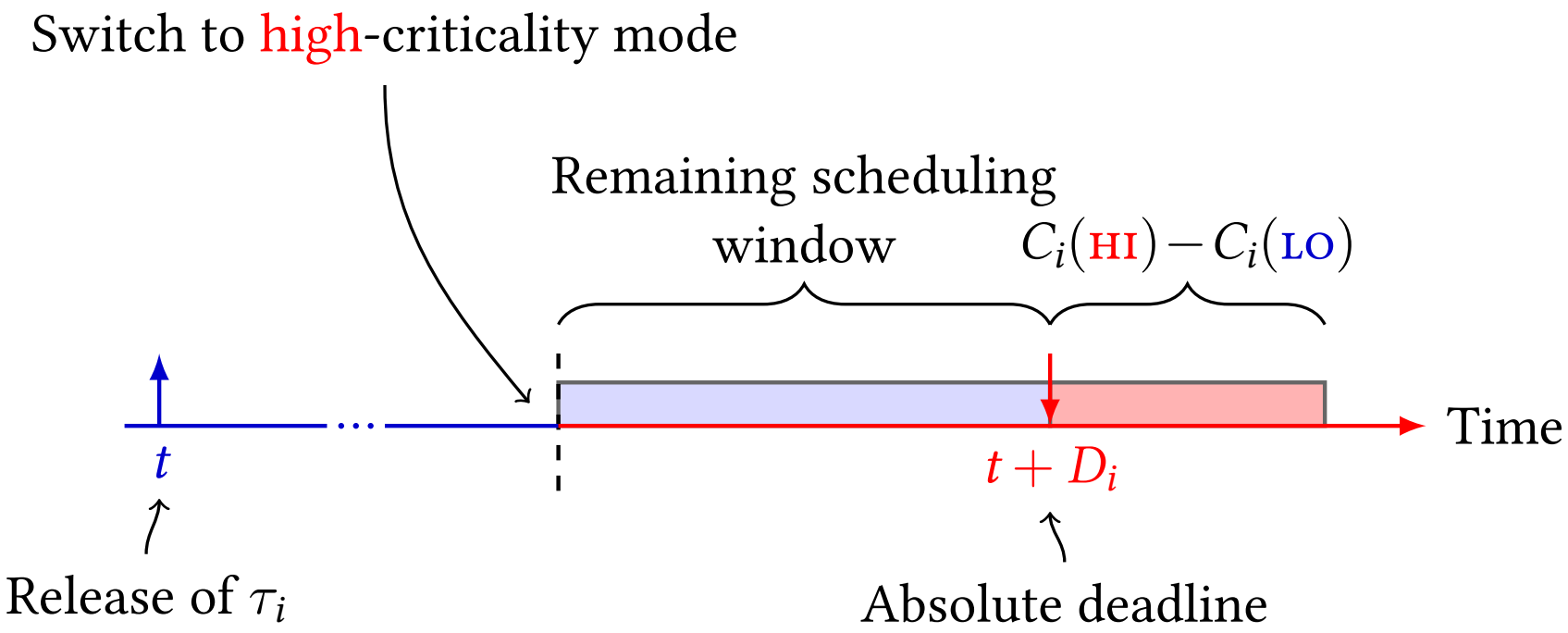
Carry-over jobs



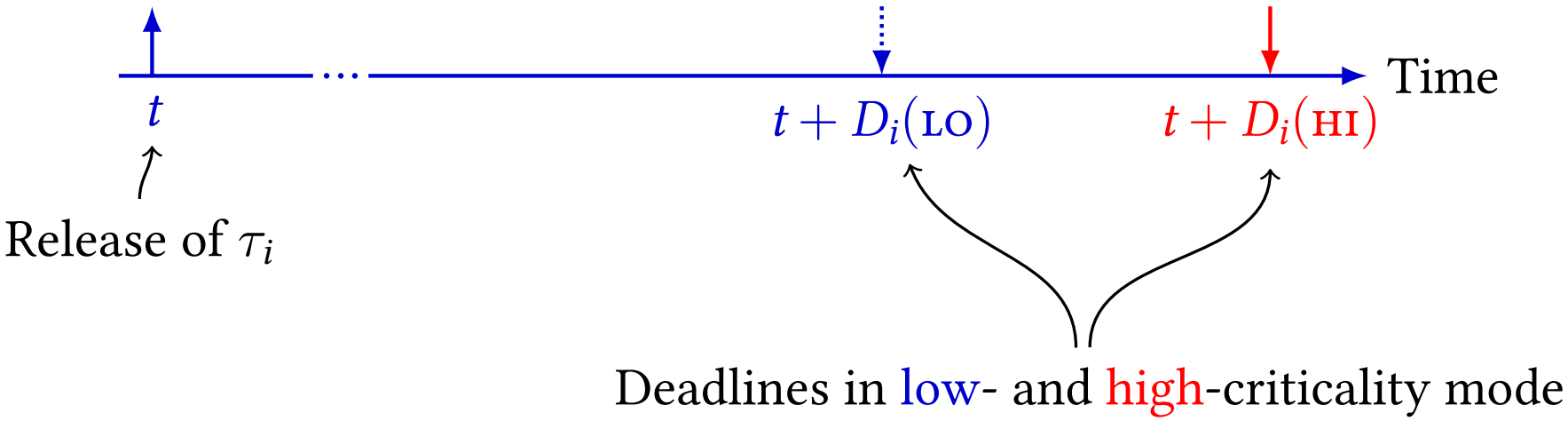
Carry-over jobs



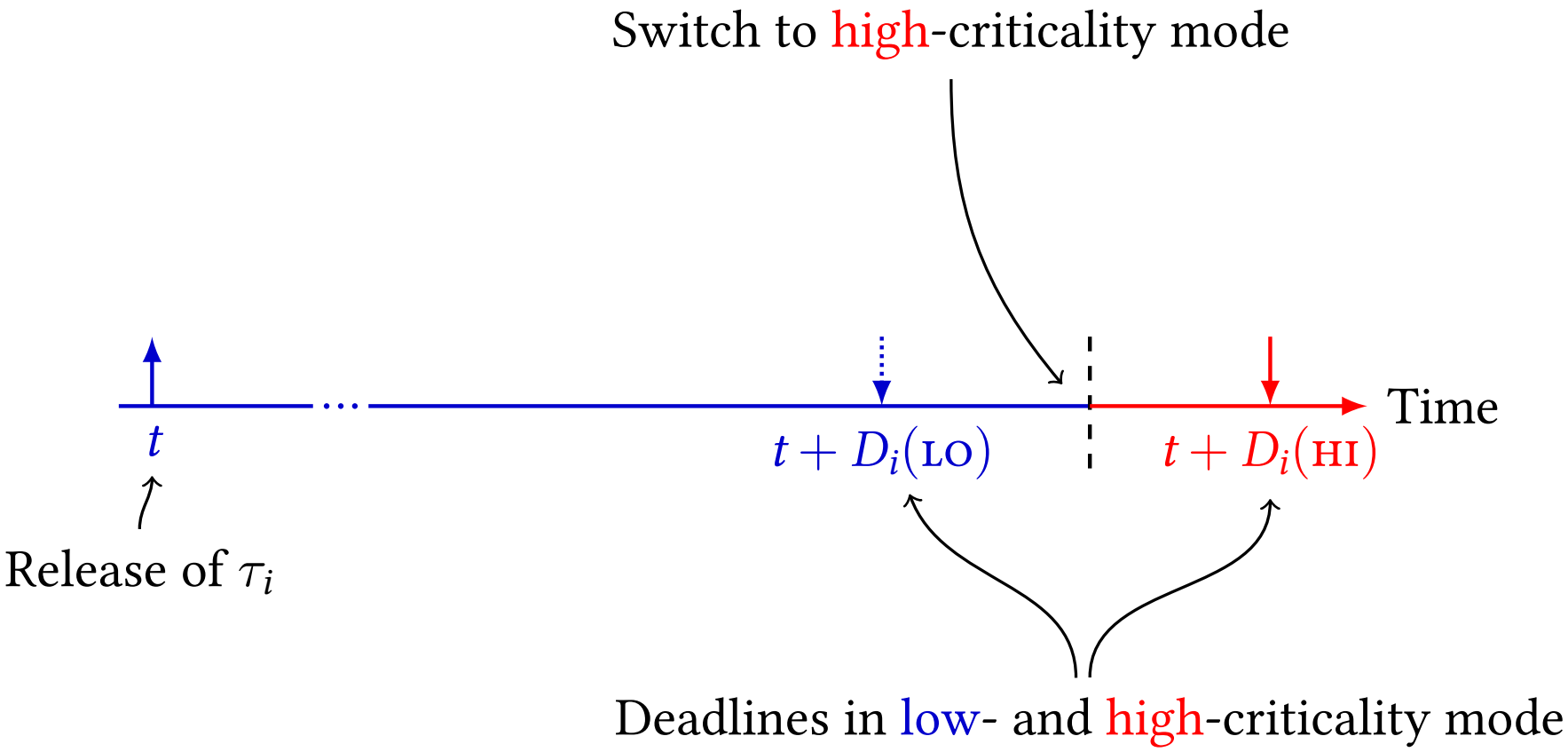
Carry-over jobs



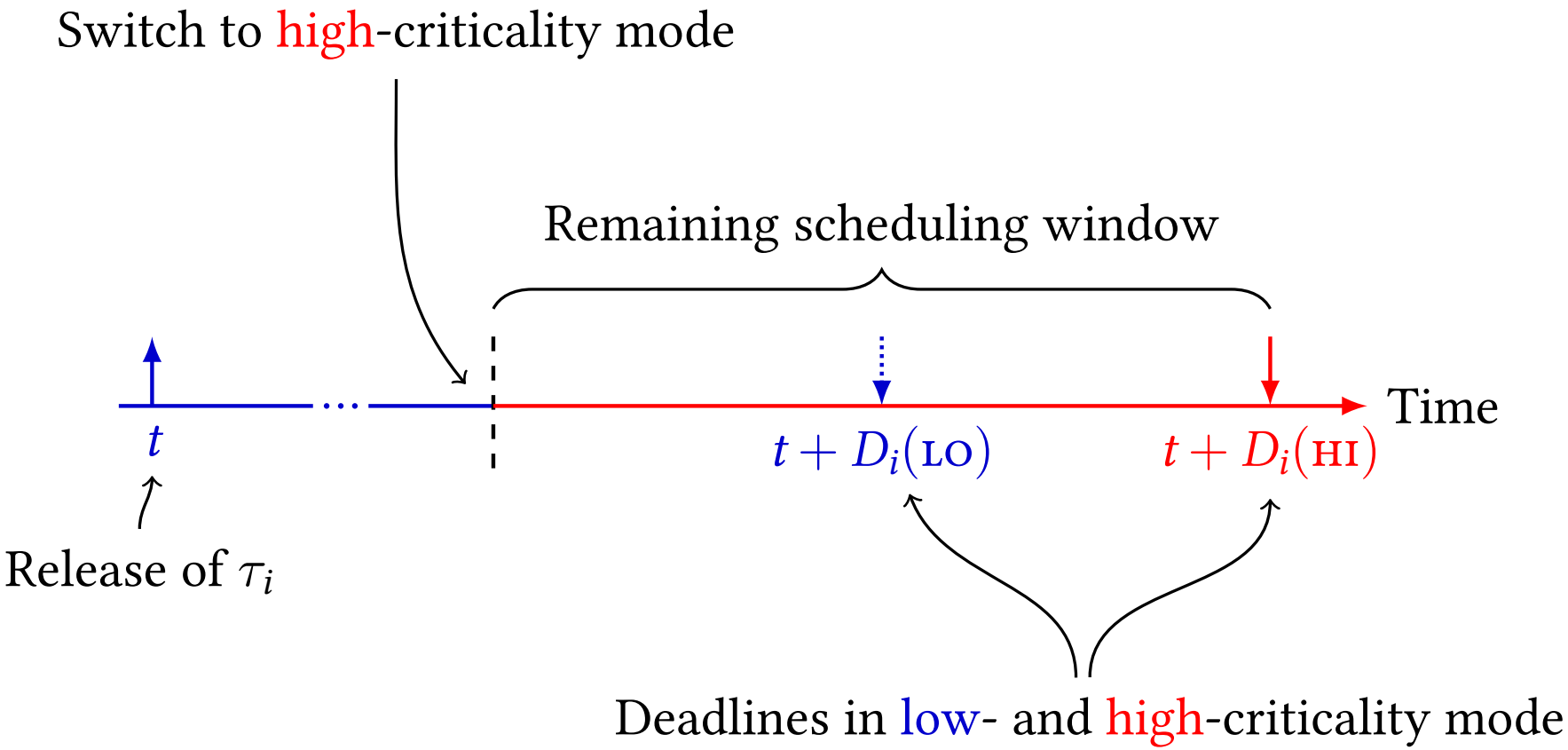
Adjusting the demand of carry-over jobs



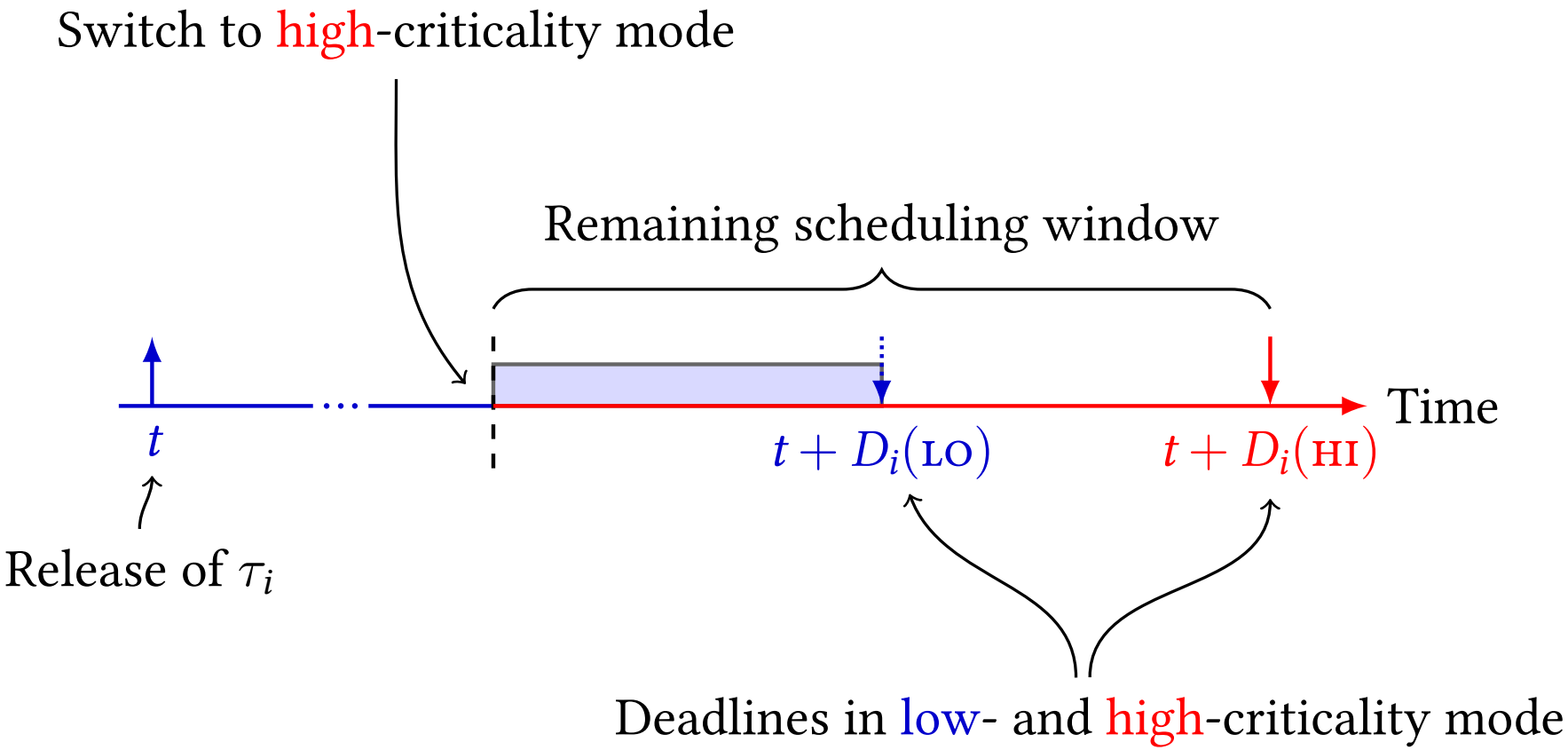
Adjusting the demand of carry-over jobs



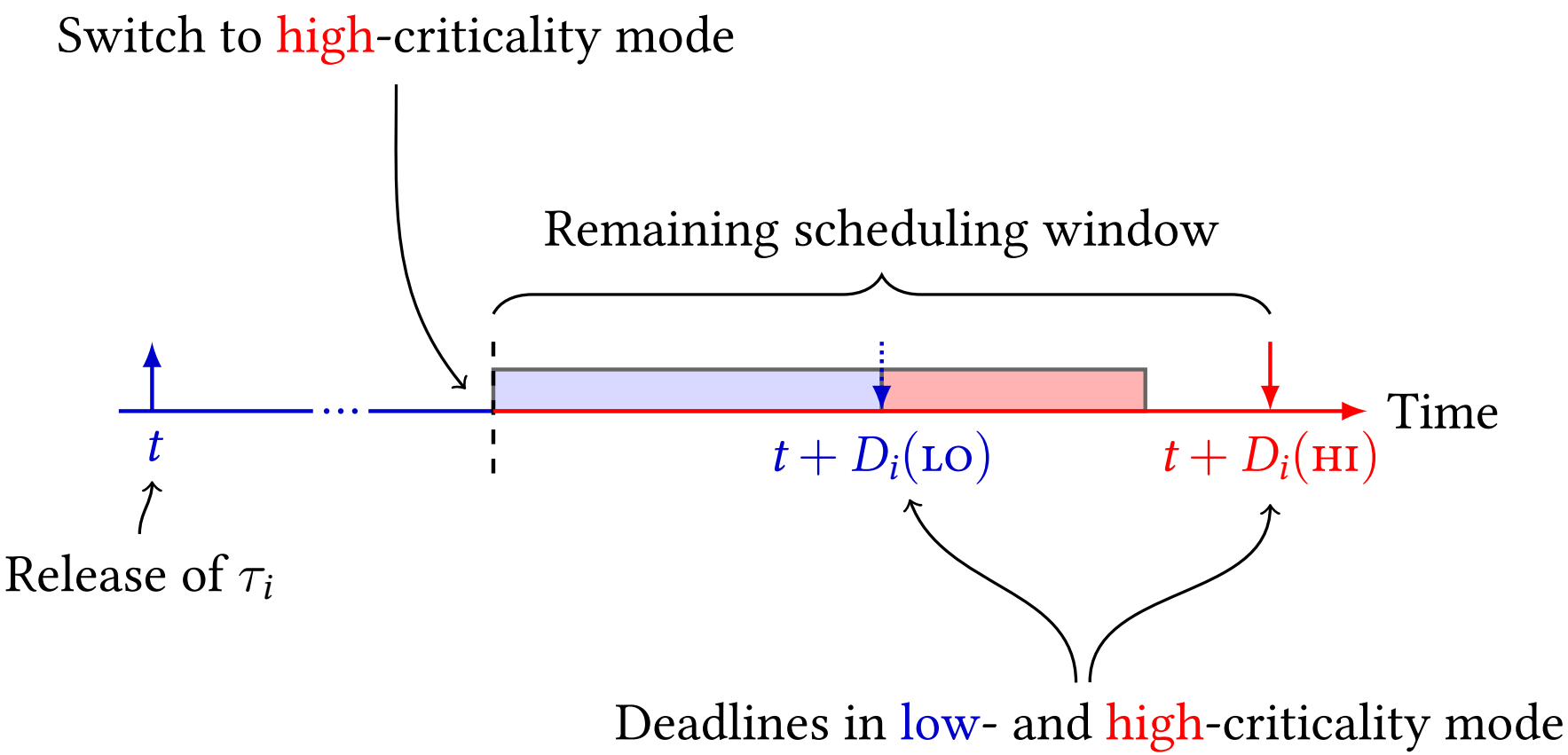
Adjusting the demand of carry-over jobs



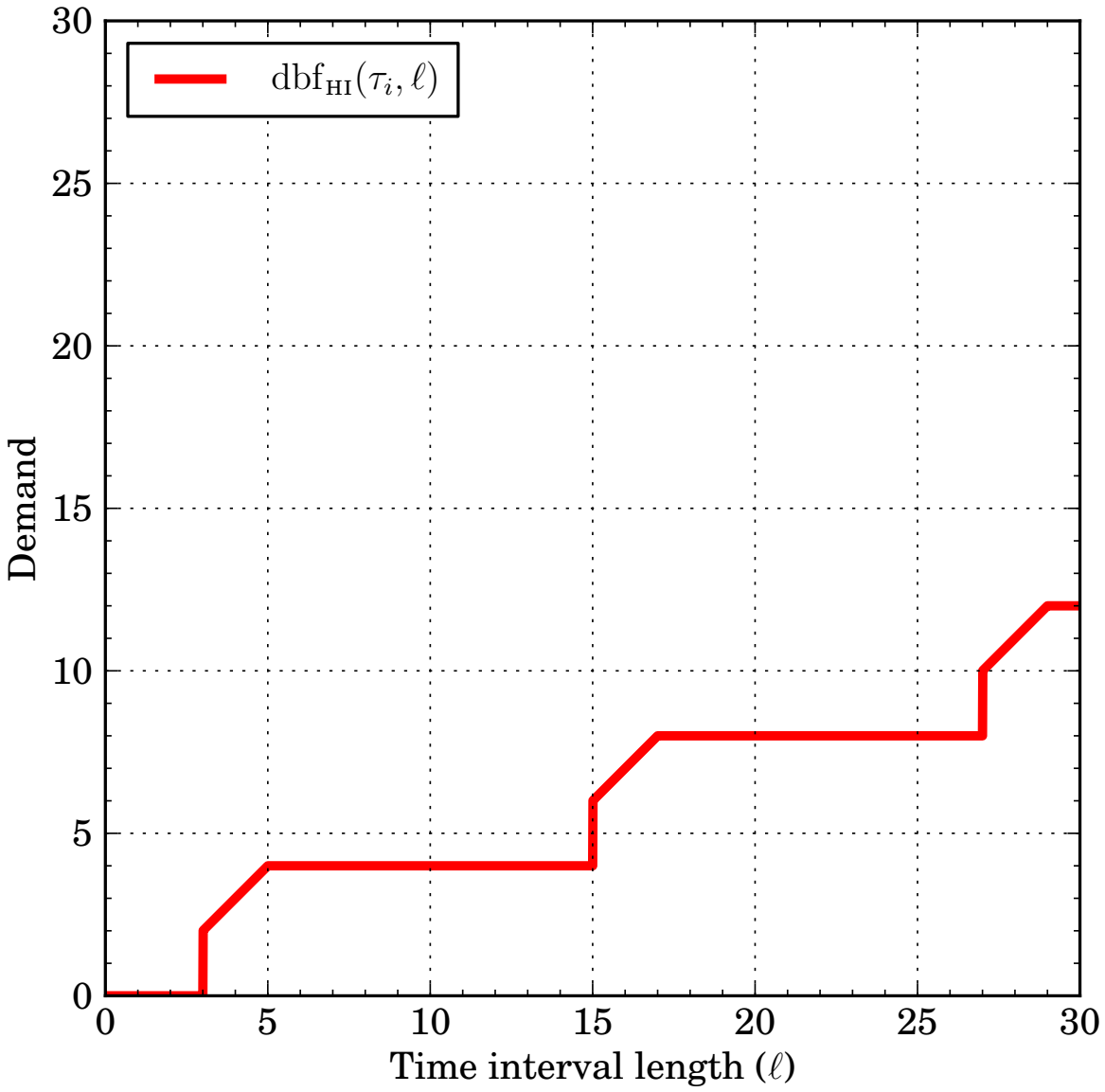
Adjusting the demand of carry-over jobs



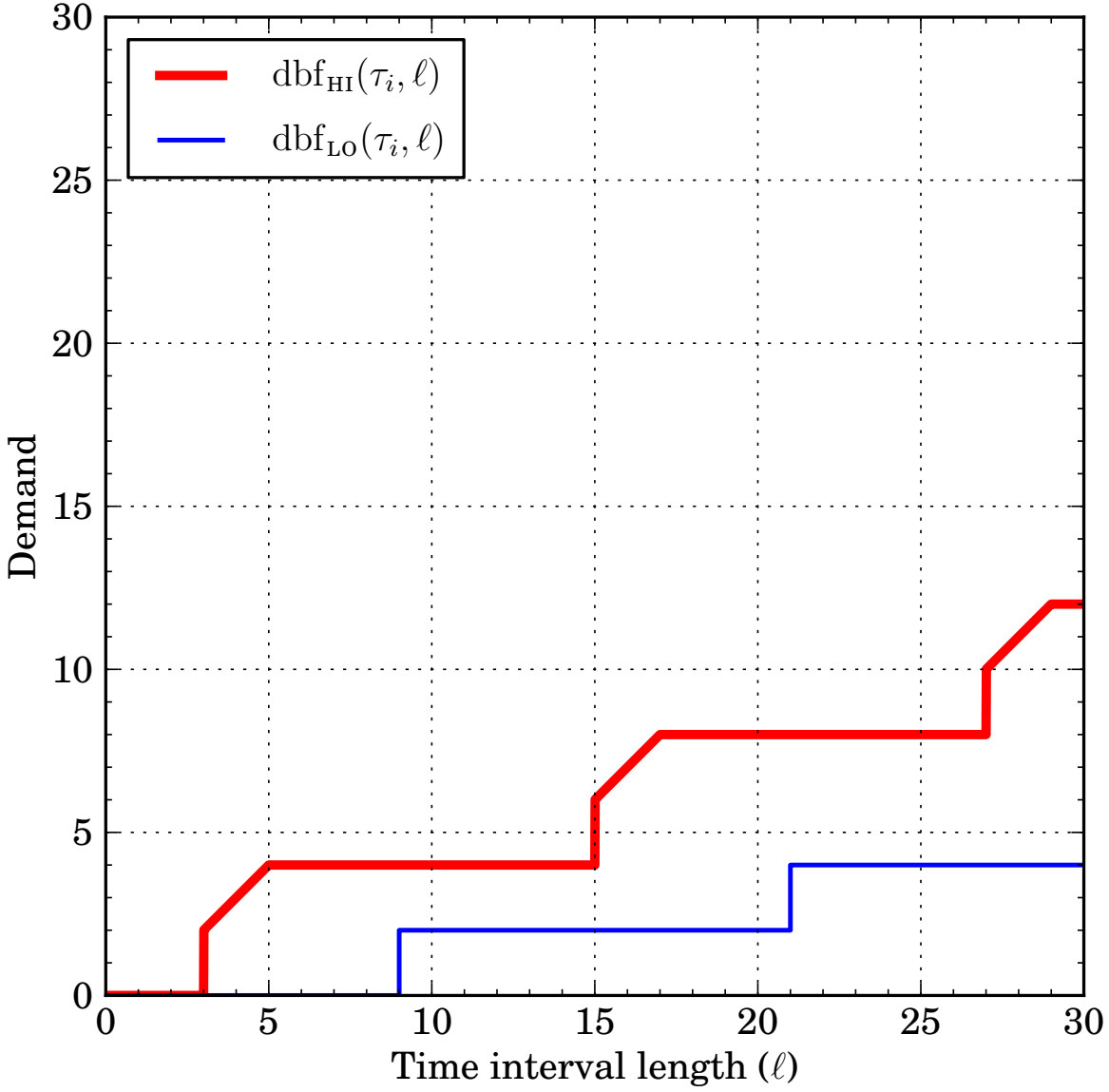
Adjusting the demand of carry-over jobs



Demand-bound functions for high-criticality mode



Demand-bound functions for high-criticality mode



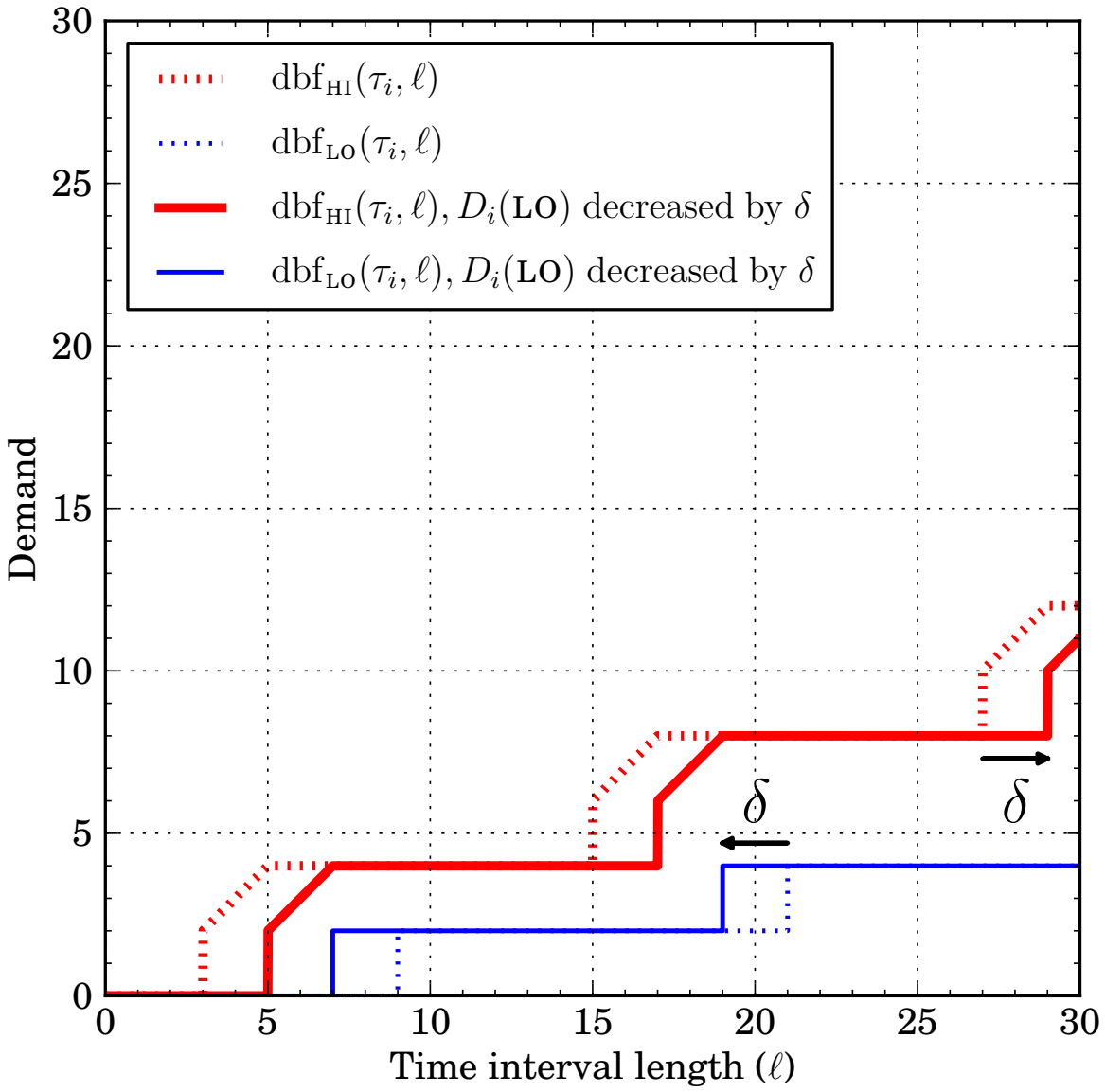
The effect of the low-criticality relative deadline

Shifting lemma

If $D_i(\text{LO})$ is decreased by $\delta \in \mathbb{Z}$, then

$$\begin{aligned} \text{dbf}_{\text{LO}}(\tau_i, \ell) &\rightsquigarrow \text{dbf}_{\text{LO}}(\tau_i, \ell + \delta) \\ \text{dbf}_{\text{HI}}(\tau_i, \ell) &\rightsquigarrow \text{dbf}_{\text{HI}}(\tau_i, \ell - \delta) \end{aligned}$$

The effect of the low-criticality relative deadline



Shaping the demand of the task set

Mixed-criticality EDF analysis

A task set τ is schedulable if both **A** and **B** hold:

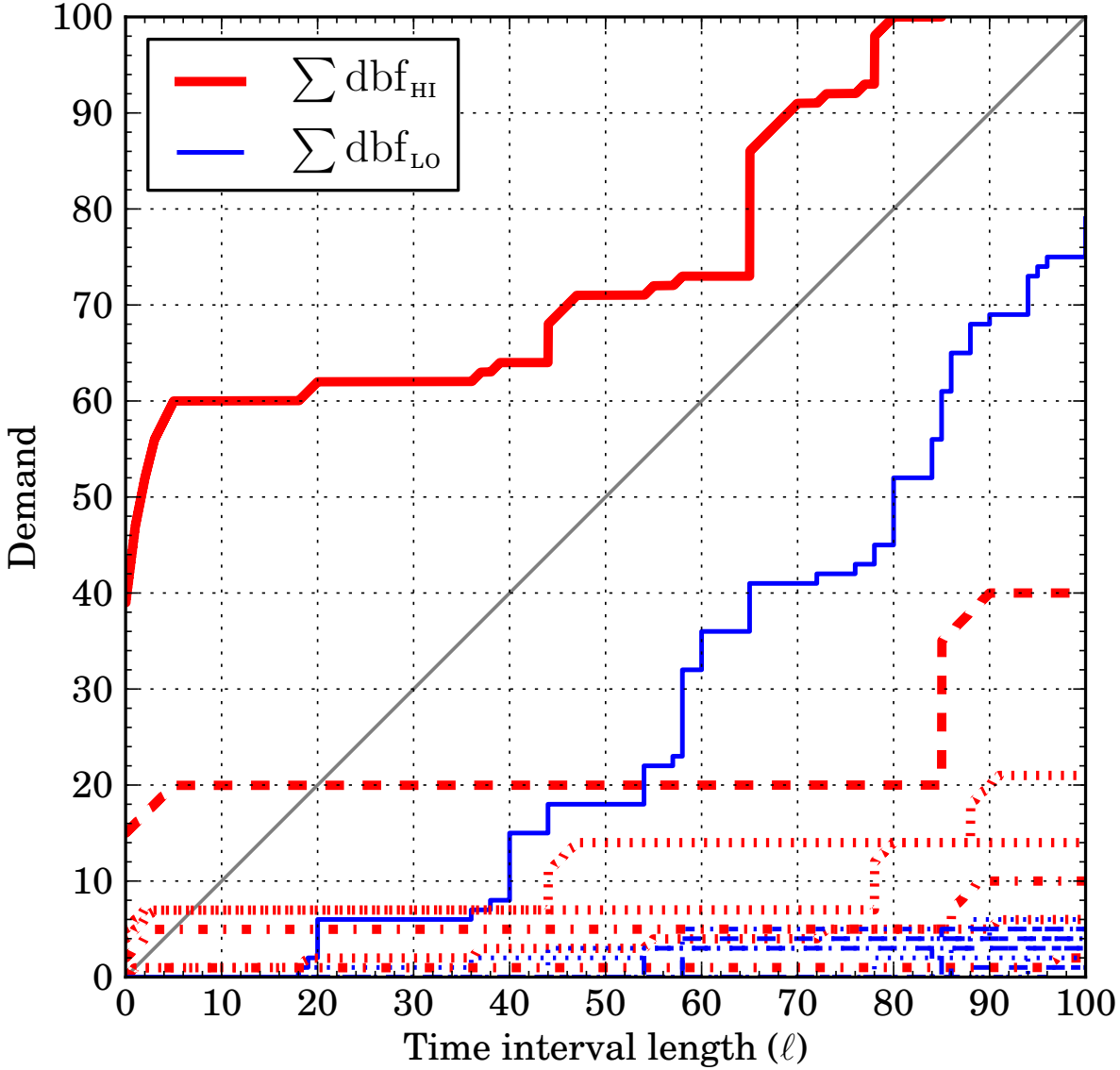
$$\mathbf{A}: \qquad \forall \ell \geqslant 0: \quad \sum_{\tau_i \in \tau} \mathrm{dbf}_{\mathrm{LO}}(\tau_i, \ell) \leqslant \mathrm{sbf}_{\mathrm{LO}}(\ell)$$

$$\mathbf{B}: \qquad \forall \ell \geqslant 0: \quad \sum_{\tau_i \in \mathrm{HI}(\tau)} \mathrm{dbf}_{\mathrm{HI}}(\tau_i, \ell) \leqslant \mathrm{sbf}_{\mathrm{HI}}(\ell)$$

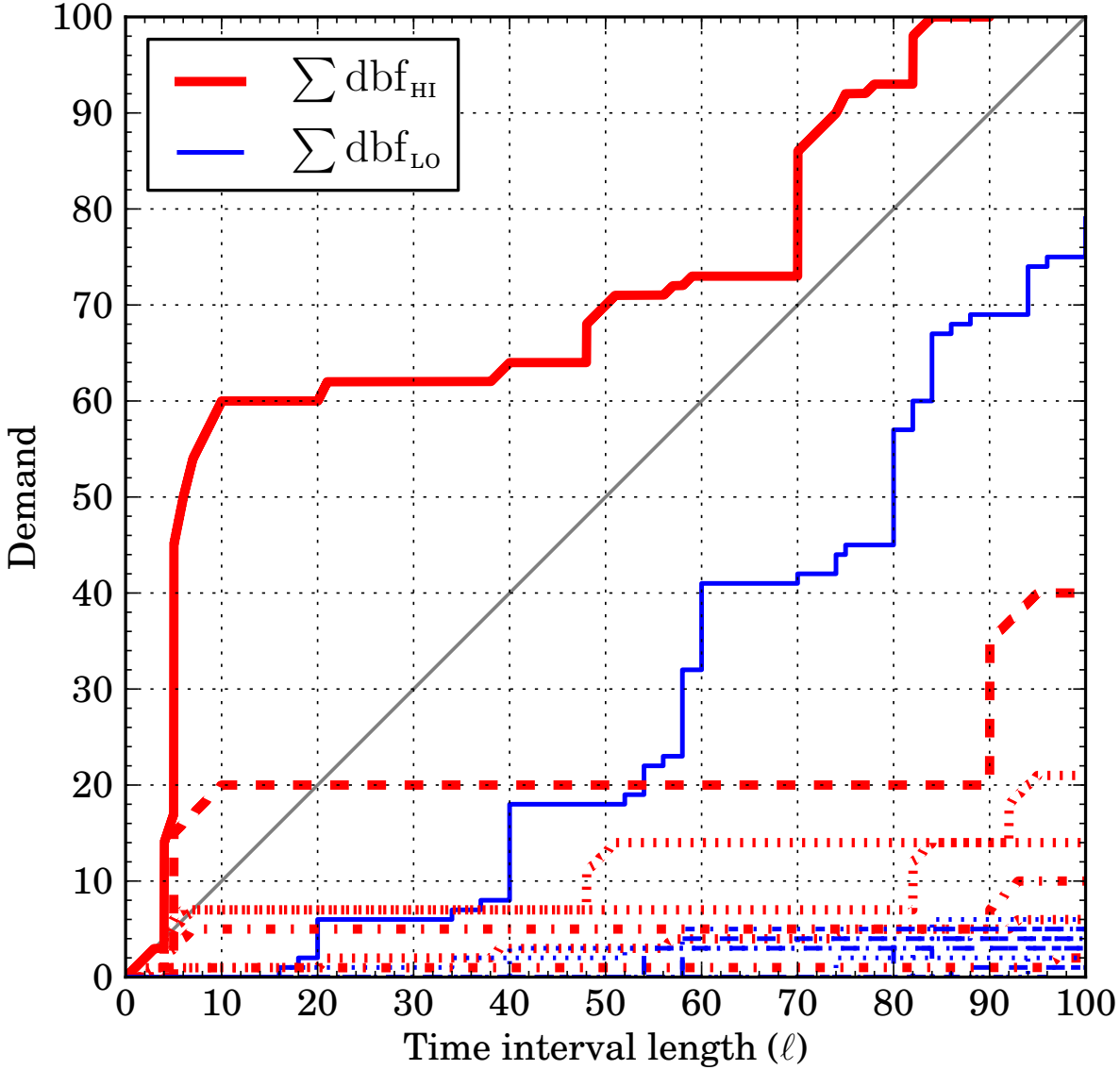
A constraint satisfaction problem

Is there a valid assignment of $D_i(\mathrm{LO})$s to each high-criticality task τ_i such that both **A** and **B** hold?

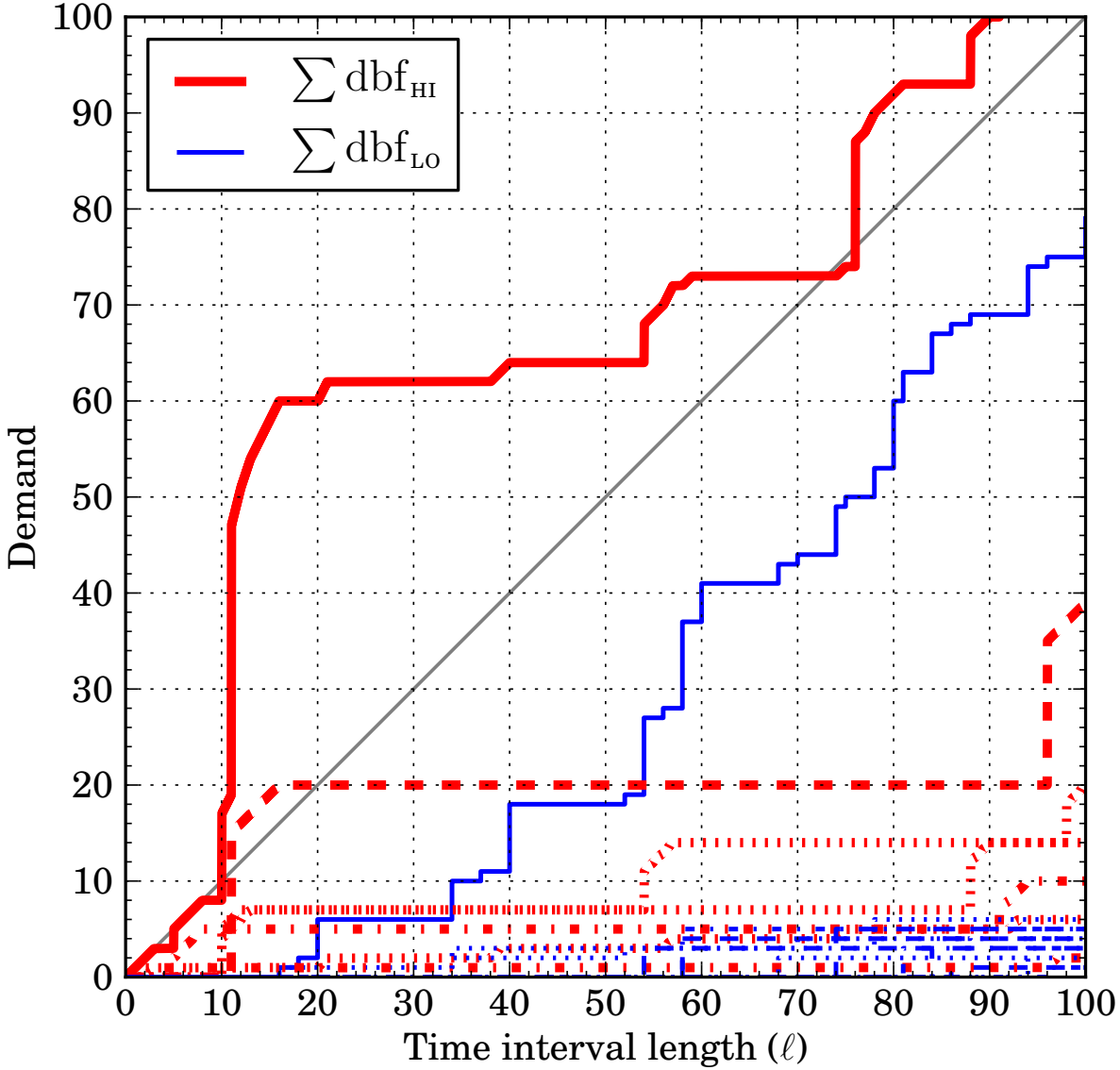
Shaping the demand of the task set



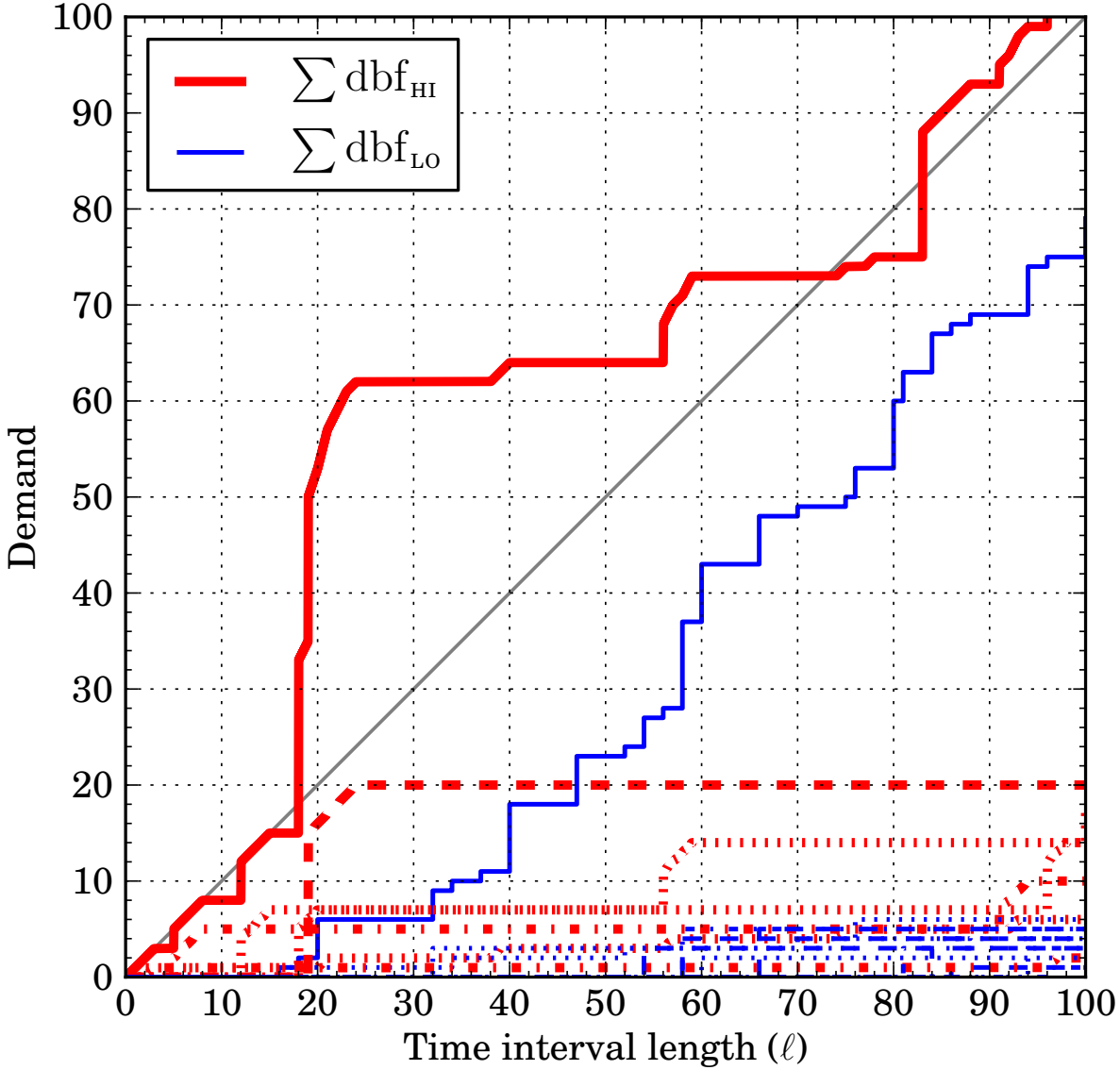
Shaping the demand of the task set



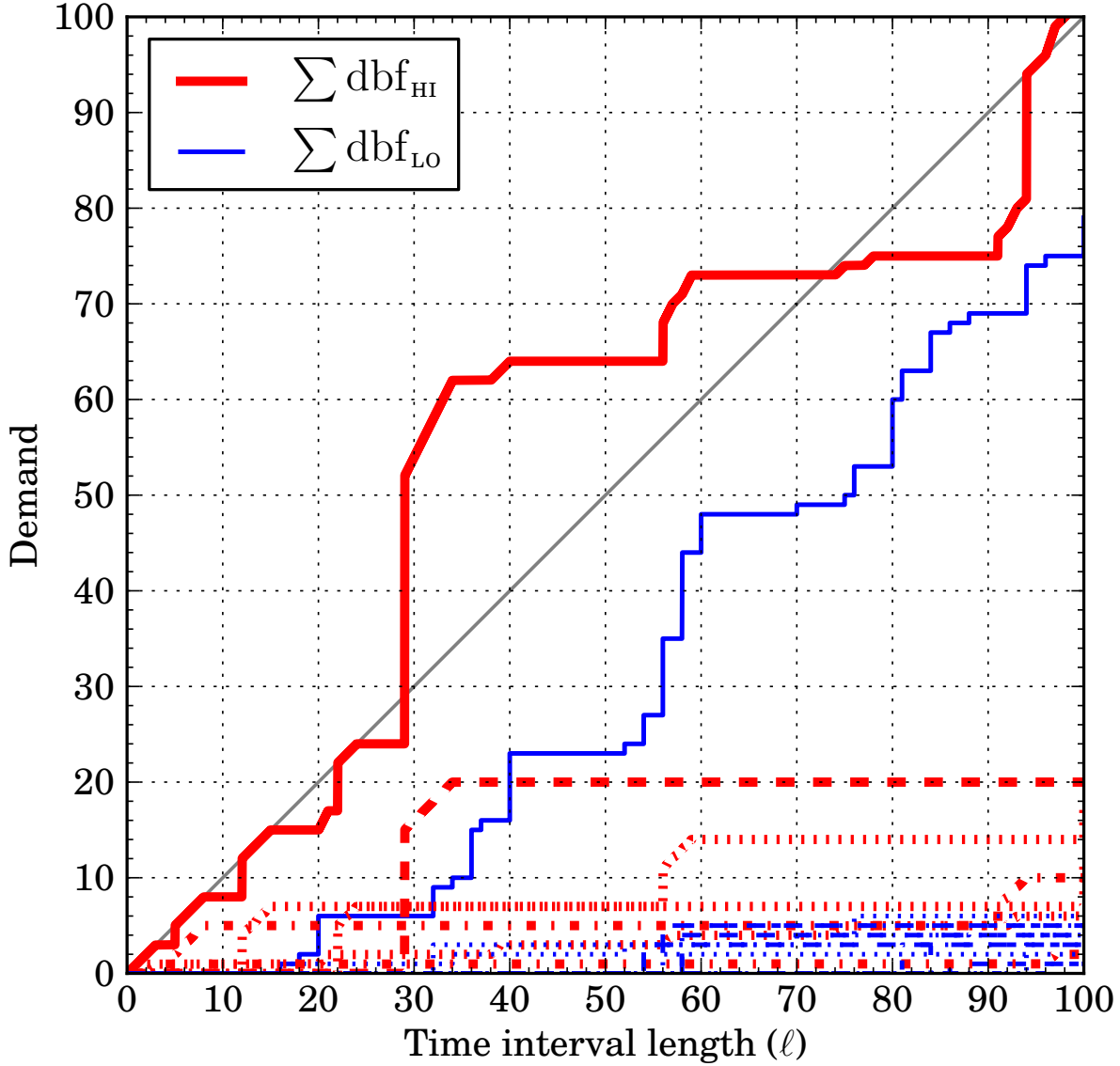
Shaping the demand of the task set



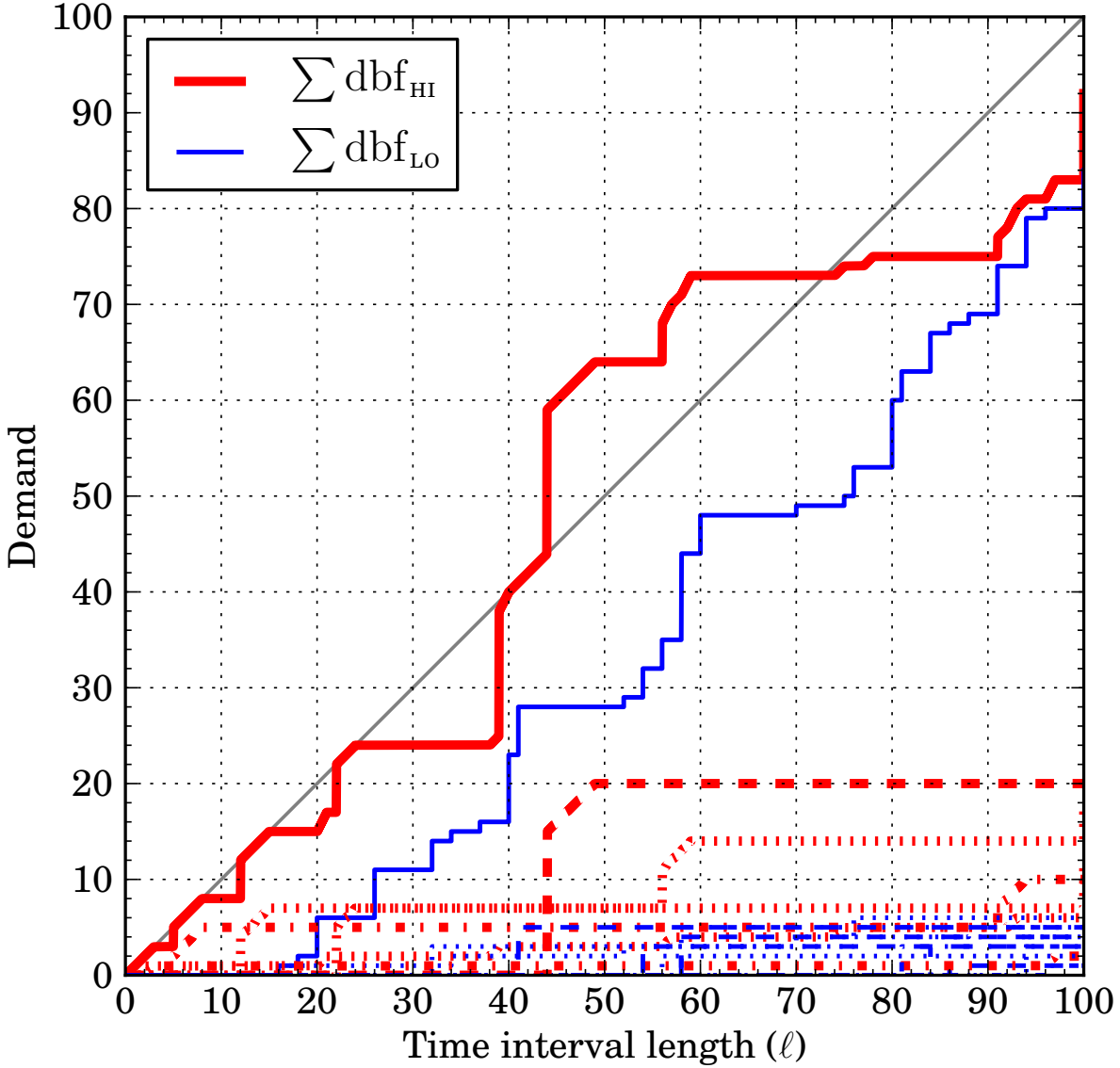
Shaping the demand of the task set



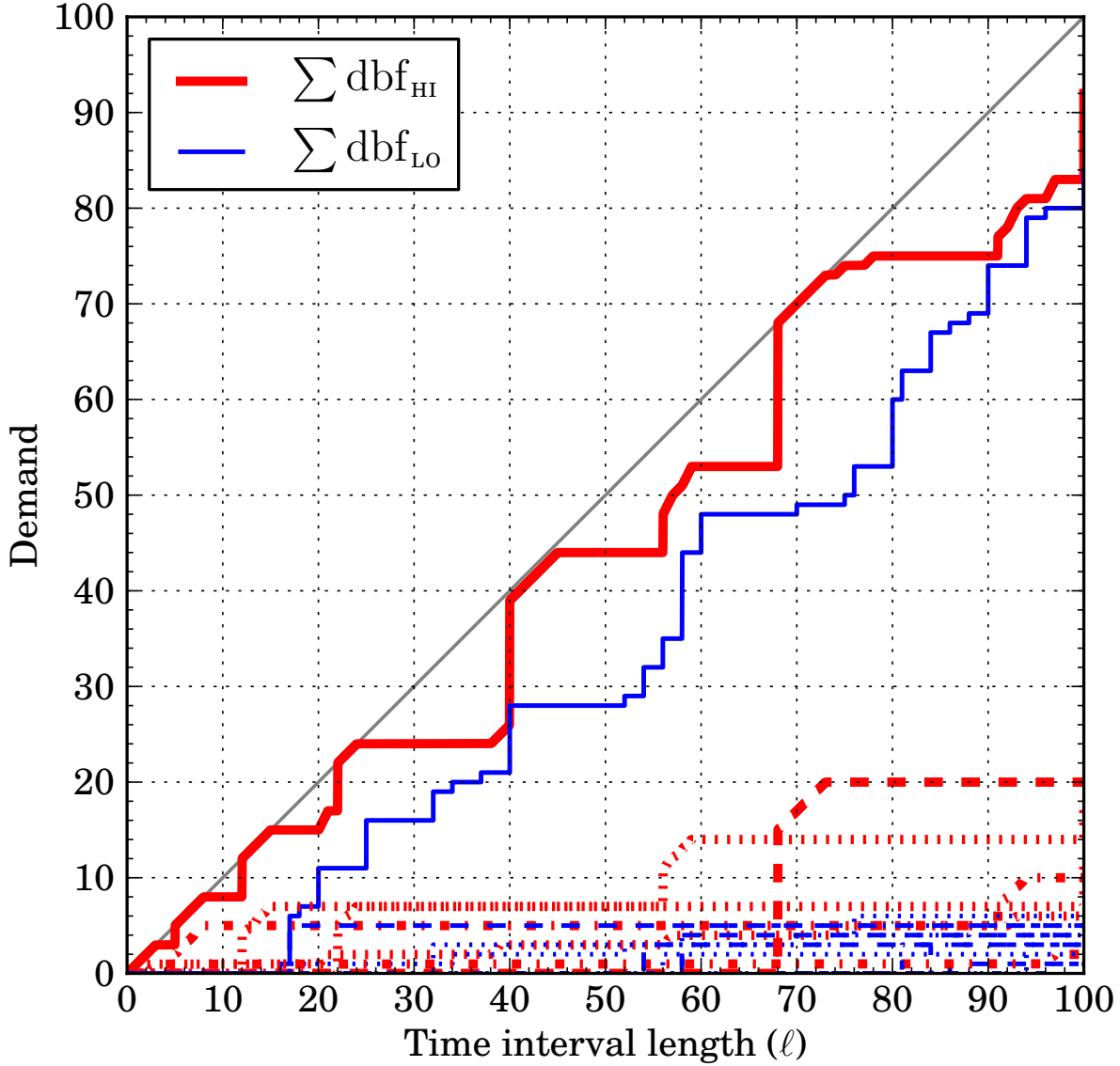
Shaping the demand of the task set



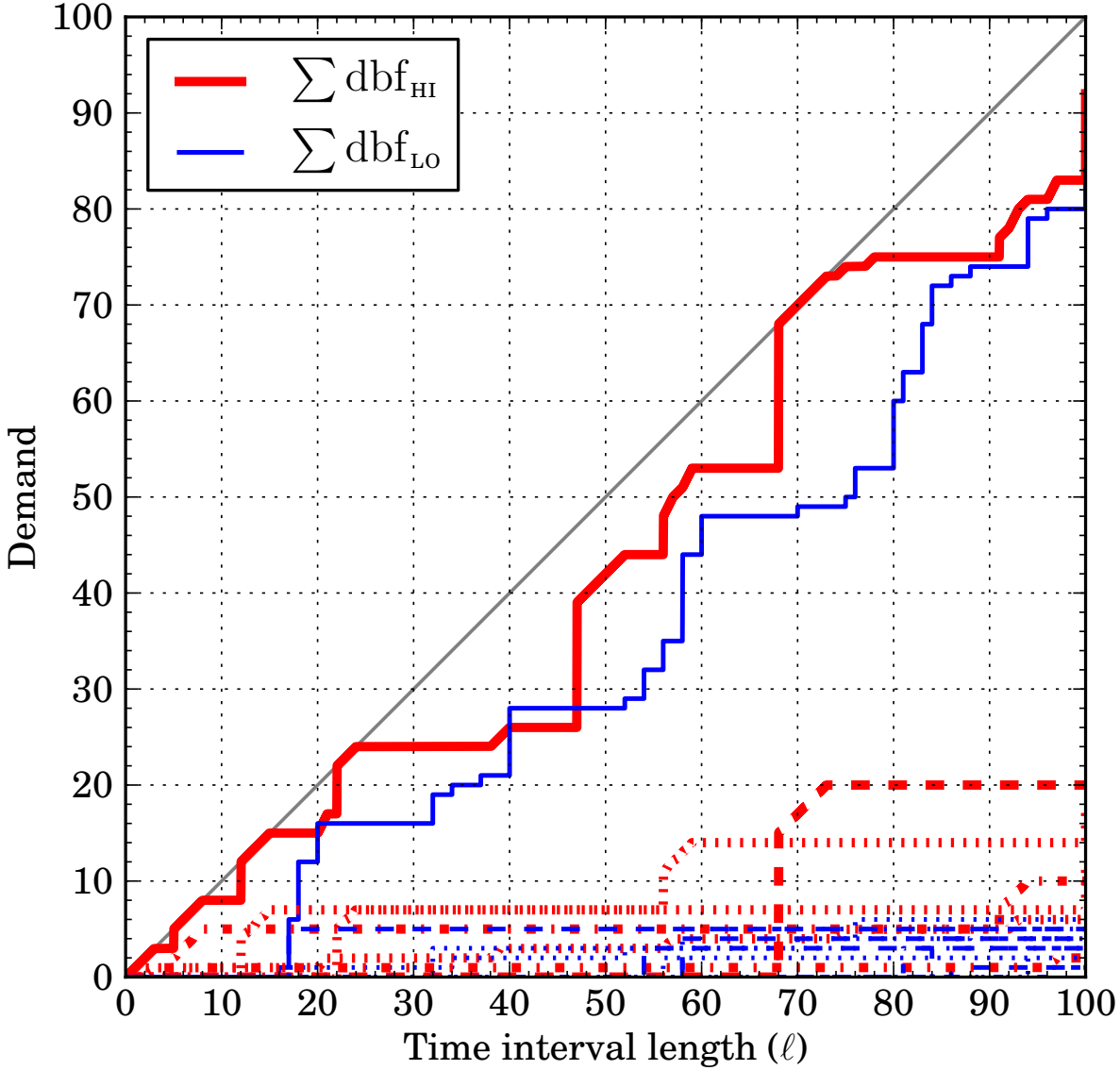
Shaping the demand of the task set



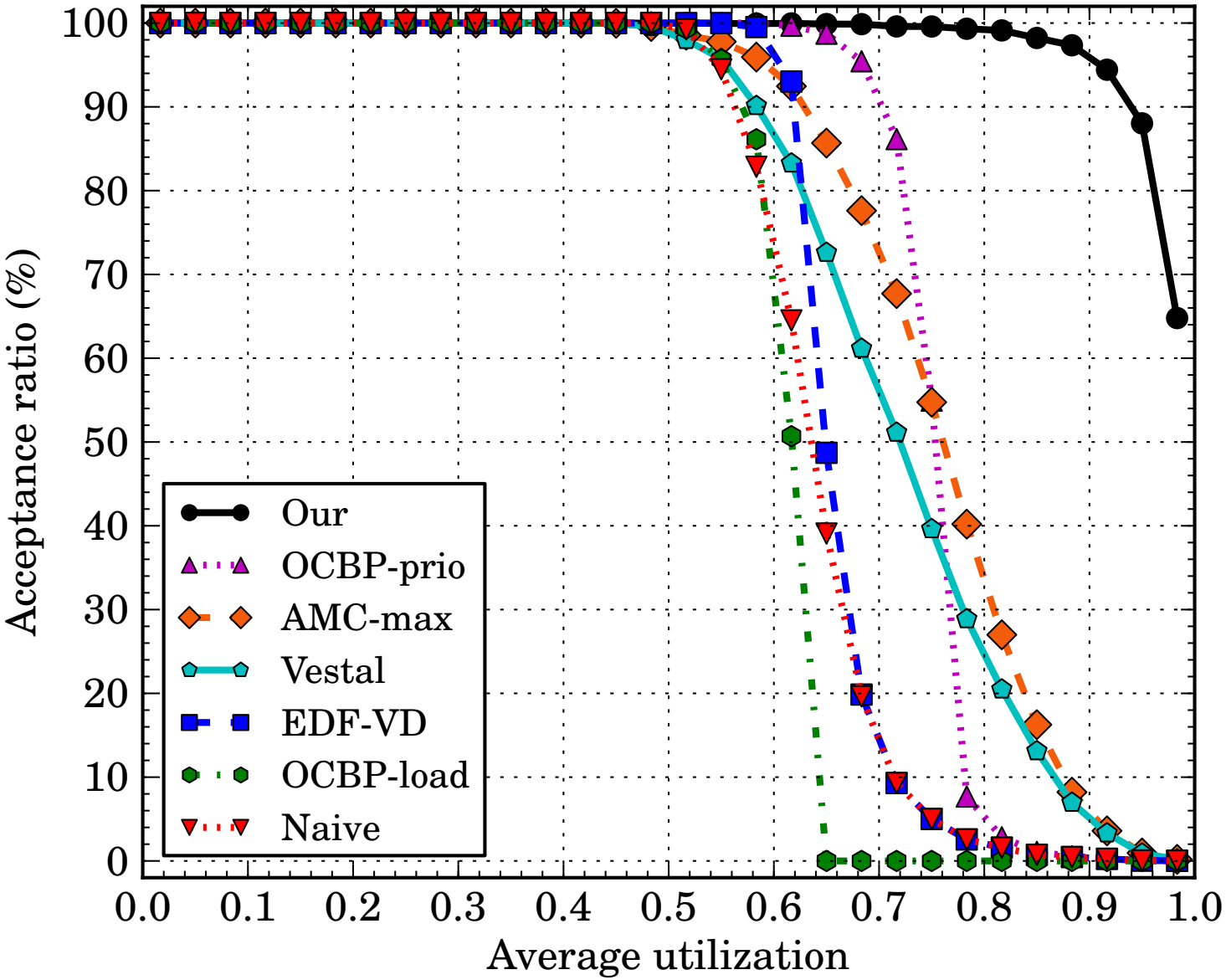
Shaping the demand of the task set



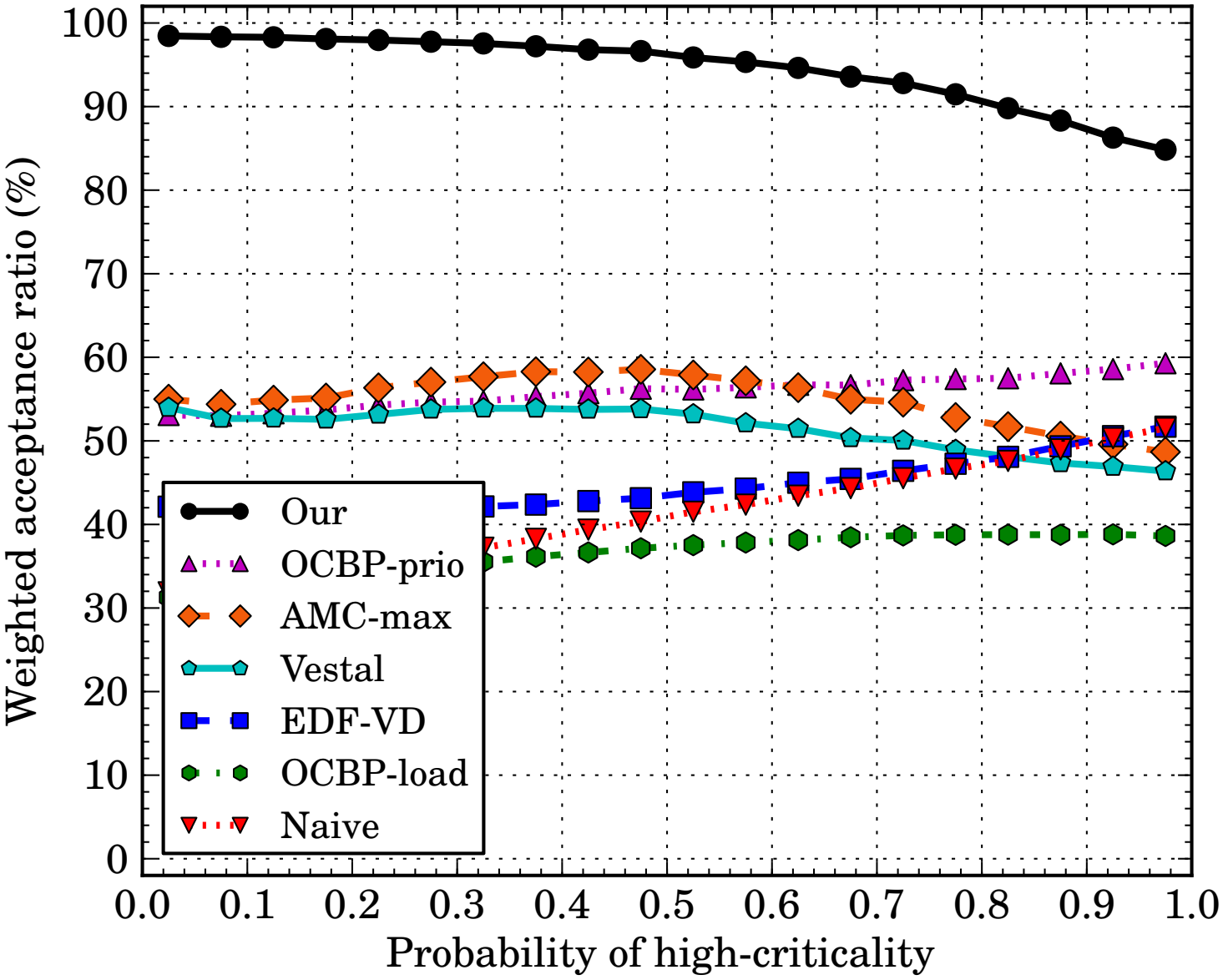
Shaping the demand of the task set



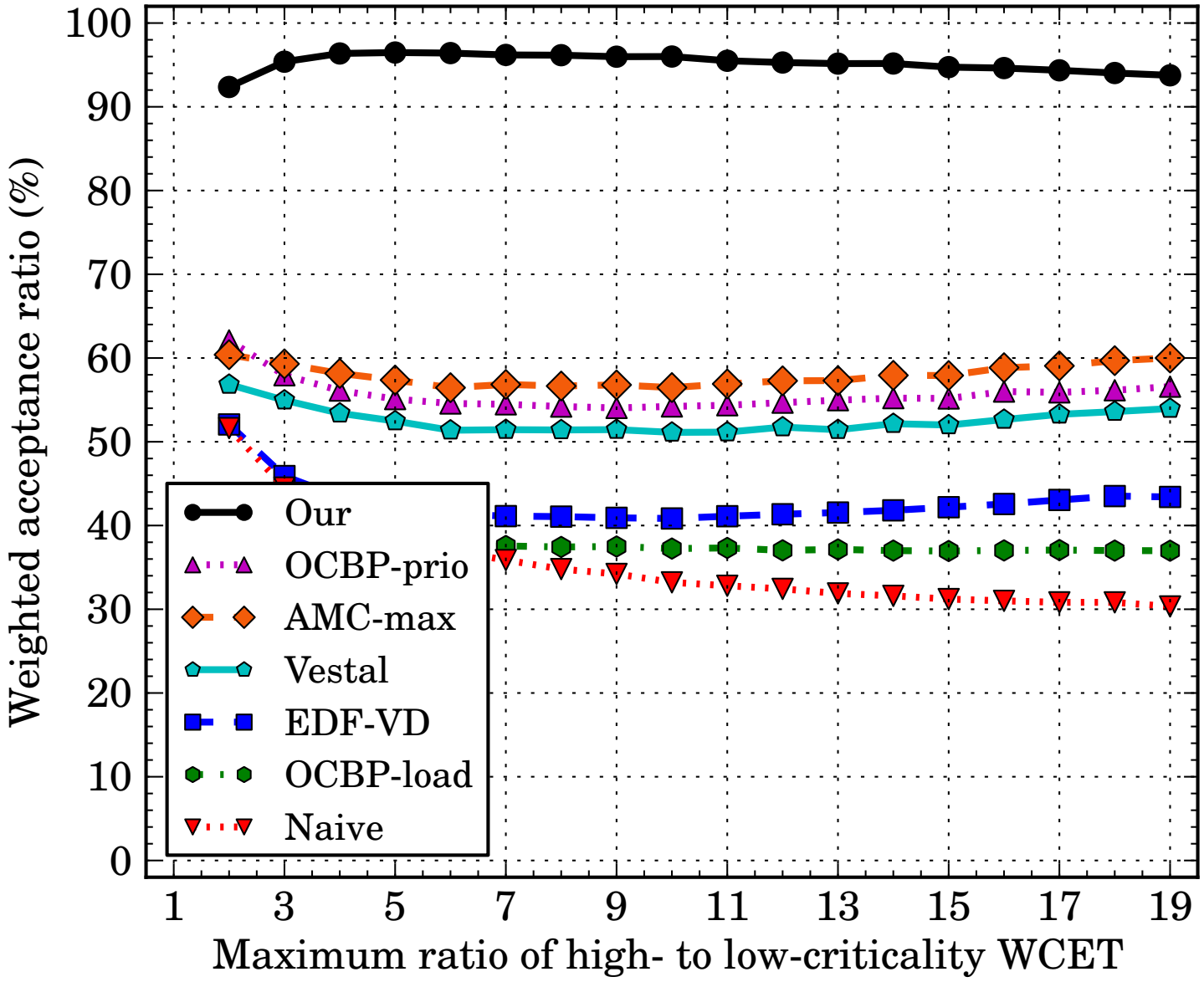
Evaluation


Acceptance ratio (%)
100
90
80
70
60
50
40
30
20
10
0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Average utilization
Our
OCBP-prio
AMC-max
Vestal
EDF-VD
OCBP-load
Naive

Evaluation


Weighted acceptance ratio (%)
100
90
80
70
60
50
40
30
20
10
0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Probability of high-criticality
Our
OCBP-prio
AMC-max
Vestal
EDF-VD
OCBP-load
Naive

Evaluation


Weighted acceptance ratio (%)
100
90
80
70
60
50
40
30
20
10
0
1
3
5
7
9
11
13
15
17
19
Maximum ratio of high- to low-criticality WCET
Our
OCBP-prio
AMC-max
Vestal
EDF-VD
OCBP-load
Naive

Conclusions

1. Demand-bound functions are useful *also for mixed-criticality systems*.
2. The particulars of mixed-criticality demand-bound functions allow us to easily *shape the demand* to the supply of the platform.
3. Experiments indicate that this approach *performs well*.

Questions?