



Matrix-DBP for (m,k) -firm real time guarantee

Ye-Qiong Song

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Matrix-DBP For (m, k) -firm Real-Time Guarantee

Based on a common work with E. Poggi, YQ. Song, Z. Wang, A. Koubâa
Partially supported by PRA SI01-04

- Part 1: context
- Part 2: where are the problems
- Part 3: Matrix-DBP
- Part 4: future work

Presentation
at



浙江大学
ZHEJIANG UNIVERSITY

Part 1: (m,k) -firm background

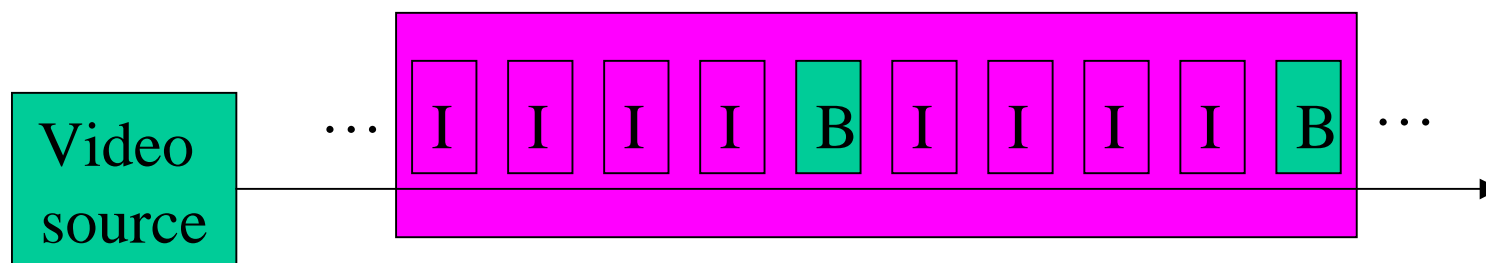


Why we interest in (m,k) -firm?

- HRT uses WC analysis leading to over sized system design (pessimistic performance estimation)
- In practice, many systems being classified HRT are not so « hard ». Occasional deadline misses can be tolerated if they are **correctly distributed**

Why we interest in (m,k)-firm?

- SRT can resolve the over-sizing problem but does not specify **how deadlines can missed**
- A probabilistic guarantee of m/k may not be sufficient (e.g. MPEG video stream composed of I, B and P packets)



Can tolerate at most 1 deadline miss of B every 10 packets

Probability of 9/10 can not be suitable

Why we interest in (m,k)-firm?

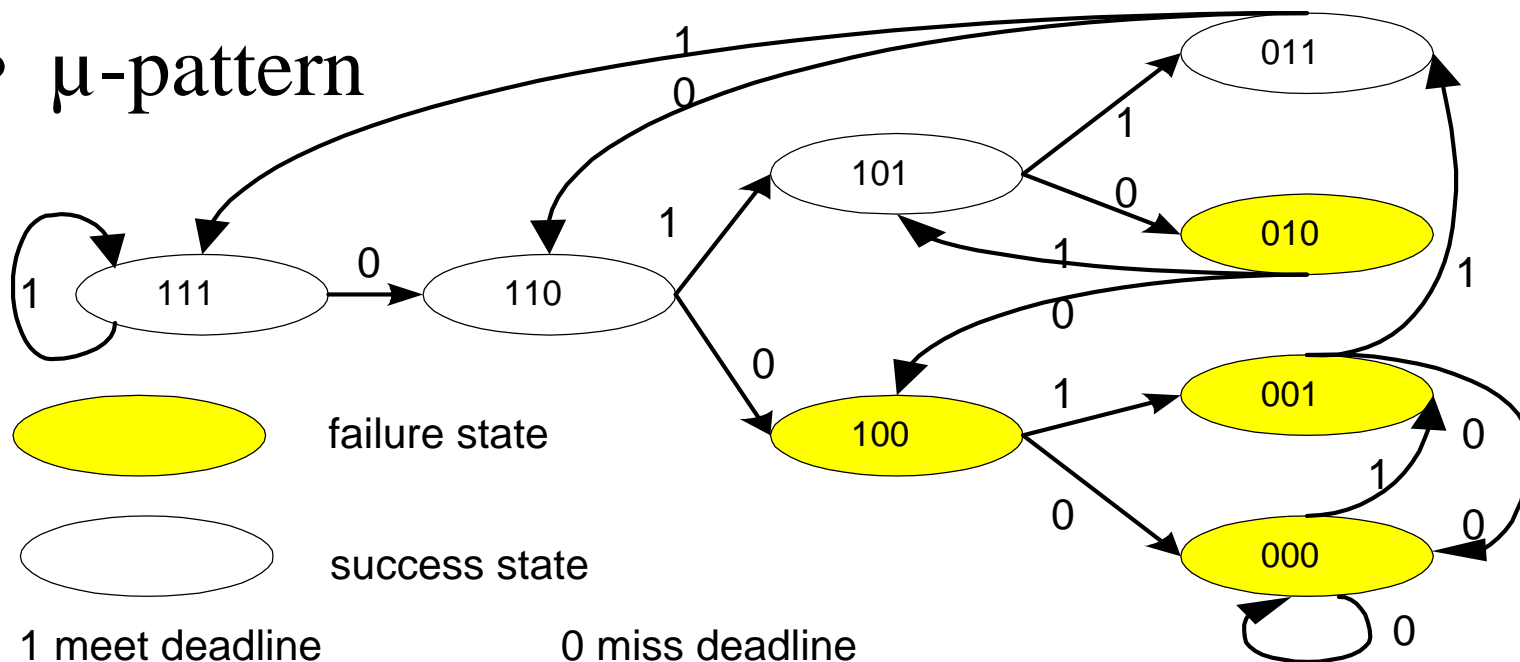
- (m,k)-firm guarantees the deadline meeting of m among any k consecutive task invocations or message transmissions
- (m,k)-firm provides a general frame for RT constraints description :
 - HRT is a particular case of (m,k)-firm with $m=k$
 - SRT guarantee with probability $p = m/k$ is a particular case of (m,k)-firm with: $p = \lim_{m,k \rightarrow \infty} \frac{m}{k}$

(m,k) -firm and WHRT

- (m,k) -firm (i.e. **at least m of k meets**) is firstly introduced by [Hamdaoui95]
- WHRT is defined by [Bernat98] and [Bernat&Burns01] to generalize (m,k) -firm:
 - (\bar{m}, \bar{k}) : **at most m misses**. But $(m, k) = (\bar{k} - \bar{m}, \bar{k})$
 - $\langle m, k \rangle$: in any k consecutive jobs, **at least m consecutive jobs are with deadline meet**
 - $\langle \bar{m}, \bar{k} \rangle = \langle \bar{m} \rangle$: **never m consecutive deadline misses** (notice that $(m, k) \leq \langle \bar{k} - m \rangle$)

(m,k)-firm

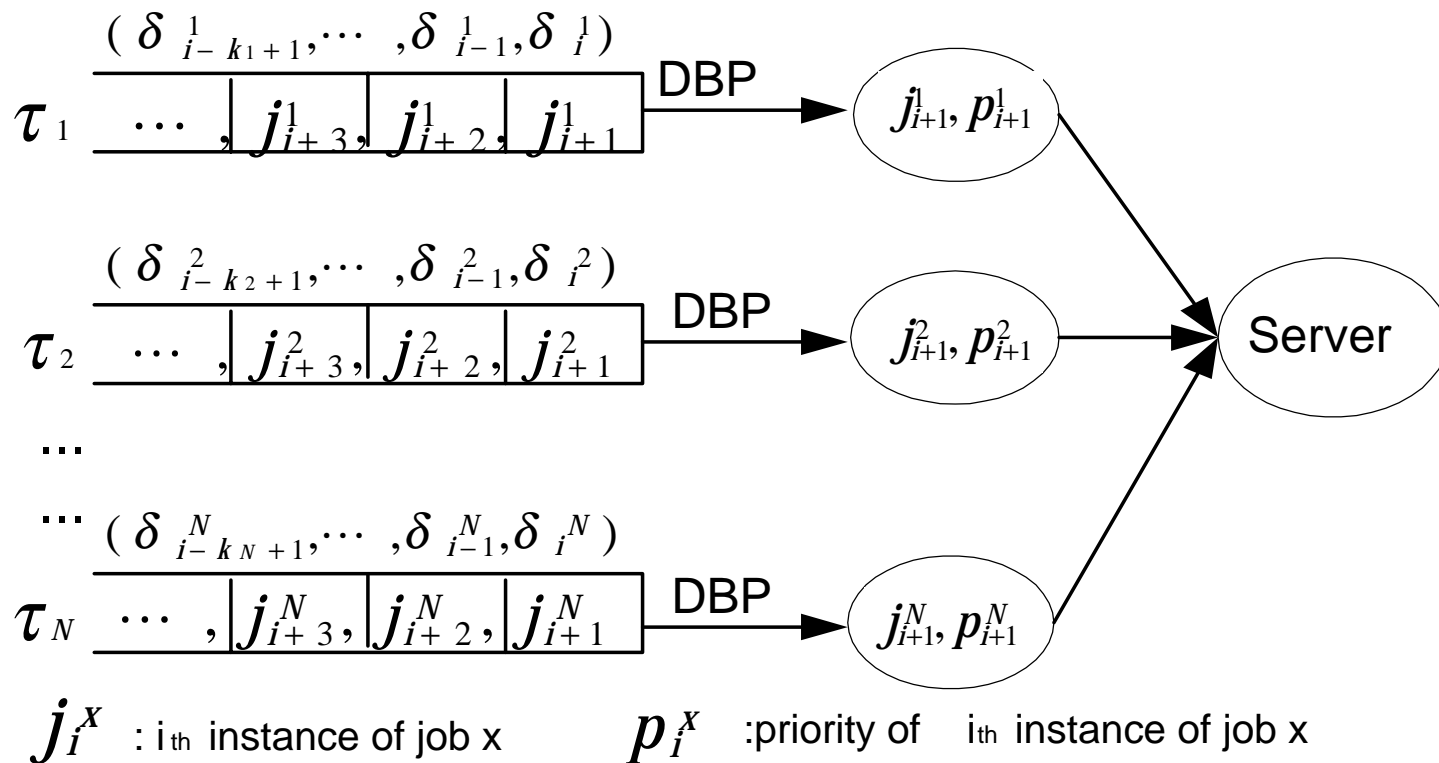
- Failure state in (m,k)-firm context
- Example of (2,3)-firm
- μ -pattern



DBP: Distance Based Priority

- DBP of a μ -pattern is defined as the number of deadline misses to arrive to a failure state
- Example: (3,5)-firm
 - (11011) has a distance of 2
 - (10111) has a distance of 3
 - (10001) has a distance of 0

DBP in MIQSS model



- A job is modeled by: $\tau_i = \{D_i, c_i, m_i, k_i\}$

Gain of DBP for (m,k)-firm

- Dynamic QoS control is possible with:
 - In case of overload, DBP allows on-line drop down of jobs according to (m_i, k_i) , reducing thus the need of resources, i.e.:

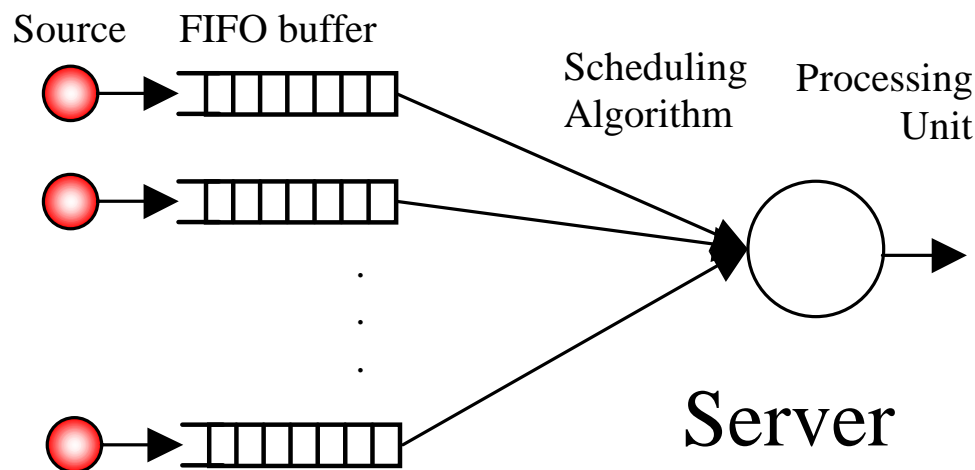
$$\sum_{i=1}^N \left[\frac{c_i}{T_i} \frac{m_i}{k_i} \right] \leq 1 \quad \text{instead of} \quad \sum_{i=1}^N \left[\frac{c_i}{T_i} \right] \leq 1$$

- Can be extended to $(m(t), k(t))$ when on-line scheduling algorithm is adopted

Part 2: where are problems?



Problems of DBP in MIQSS for RT



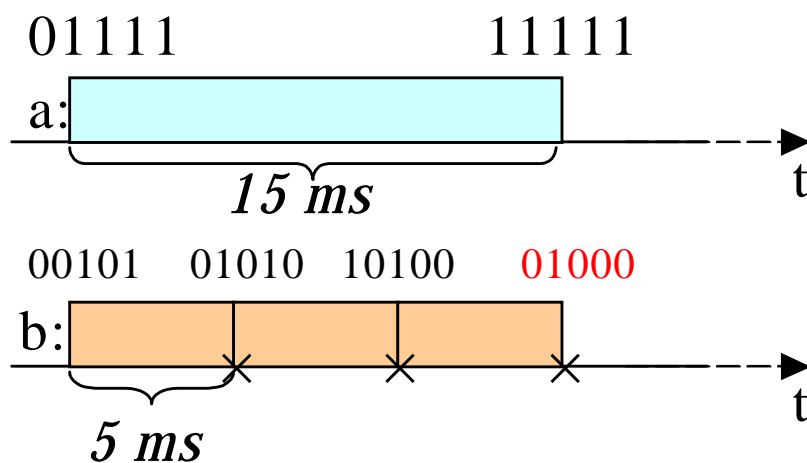
- A job is modeled by: $\tau_i = \{T_i, D_i, c_i, m_i, k_i\}$
- Pb1: how to choose when several jobs have the same priority? (DBP+EDF?)
- Pb2: how to take into account the relative importance among jobs of all sources ?

Un example of Pb2

| | (m,k)- constraint | Service time (ms) | Period/ Deadline | Initial μ - pattern |
|-----------|----------------------|----------------------|---------------------|----------------------------|
| Sa | (4,5) | 15 | 30 | {01111} |
| Sb | (2,5) | 2 | 5 | {00101} |

2

3



processing firstly Sa
will lead to failure
state of Sb !

So notion of
relative criticality
should be defined

Need of new *non-preemptive* scheduling algo.

- Should take into account:
 - (m,k)-firm constraint
 - Other temporal parameters & constraints: T_i , D_i , c_i
 - Relative criticality between streams (*a matrix can be used to represent it*)
- Should be of low implementation cost

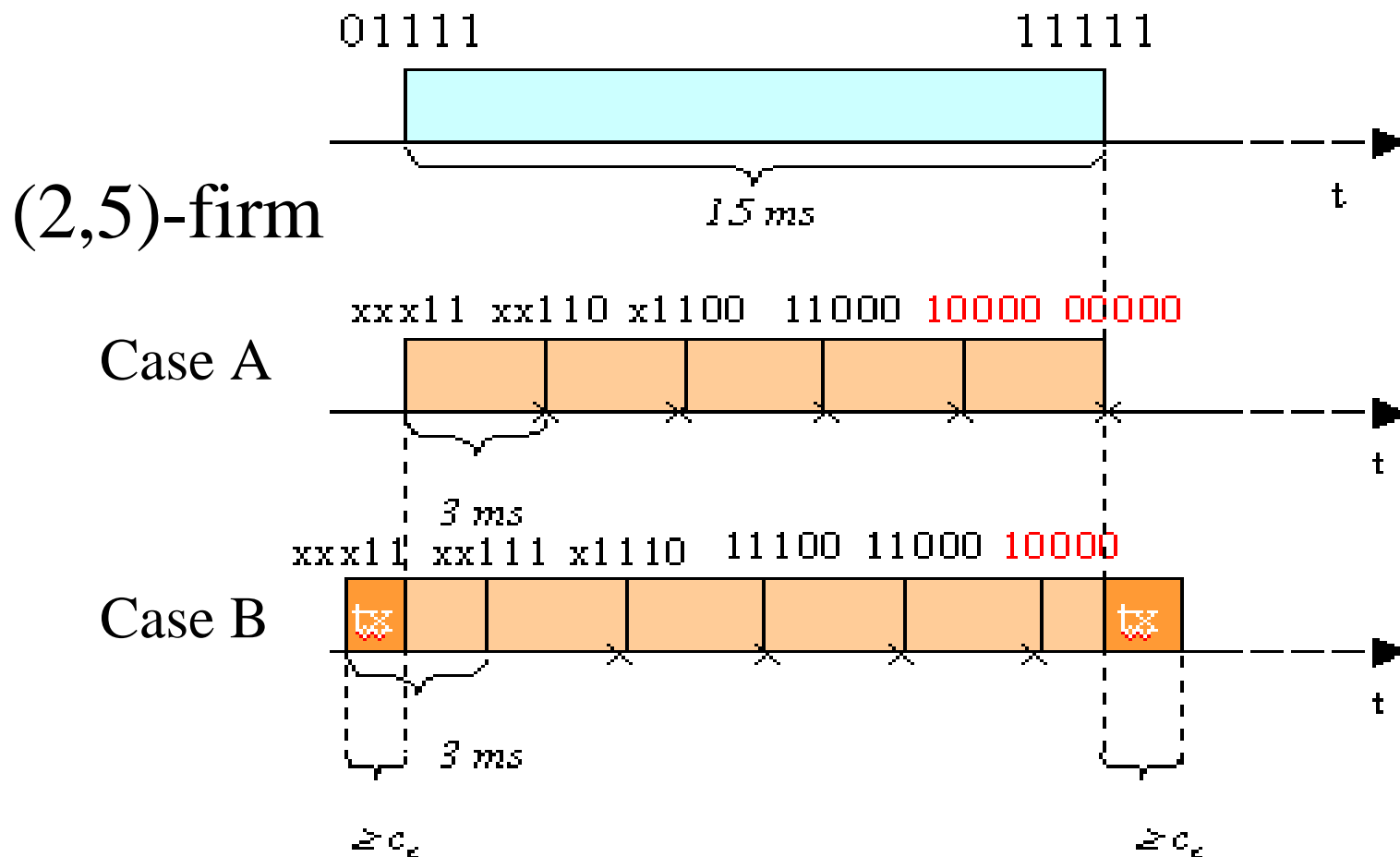


Matrix-DBP can meet all these requirements

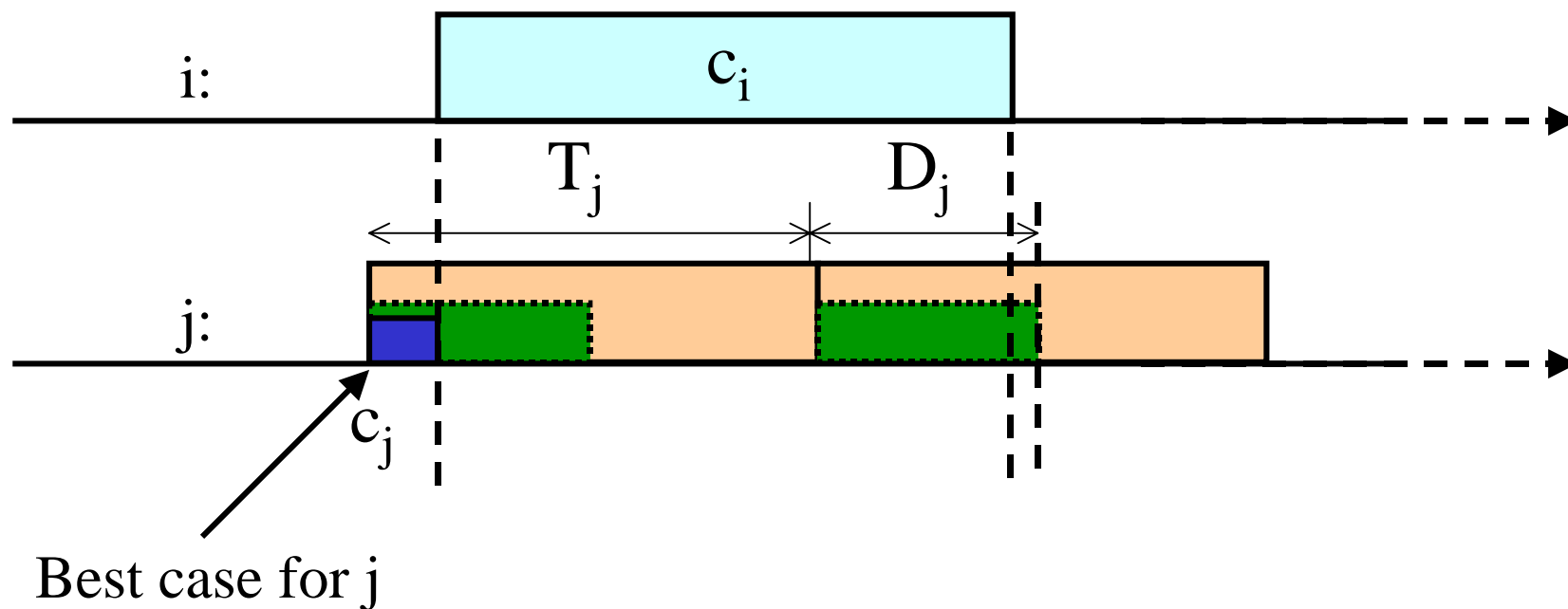
Part 3: Matrix-DBP



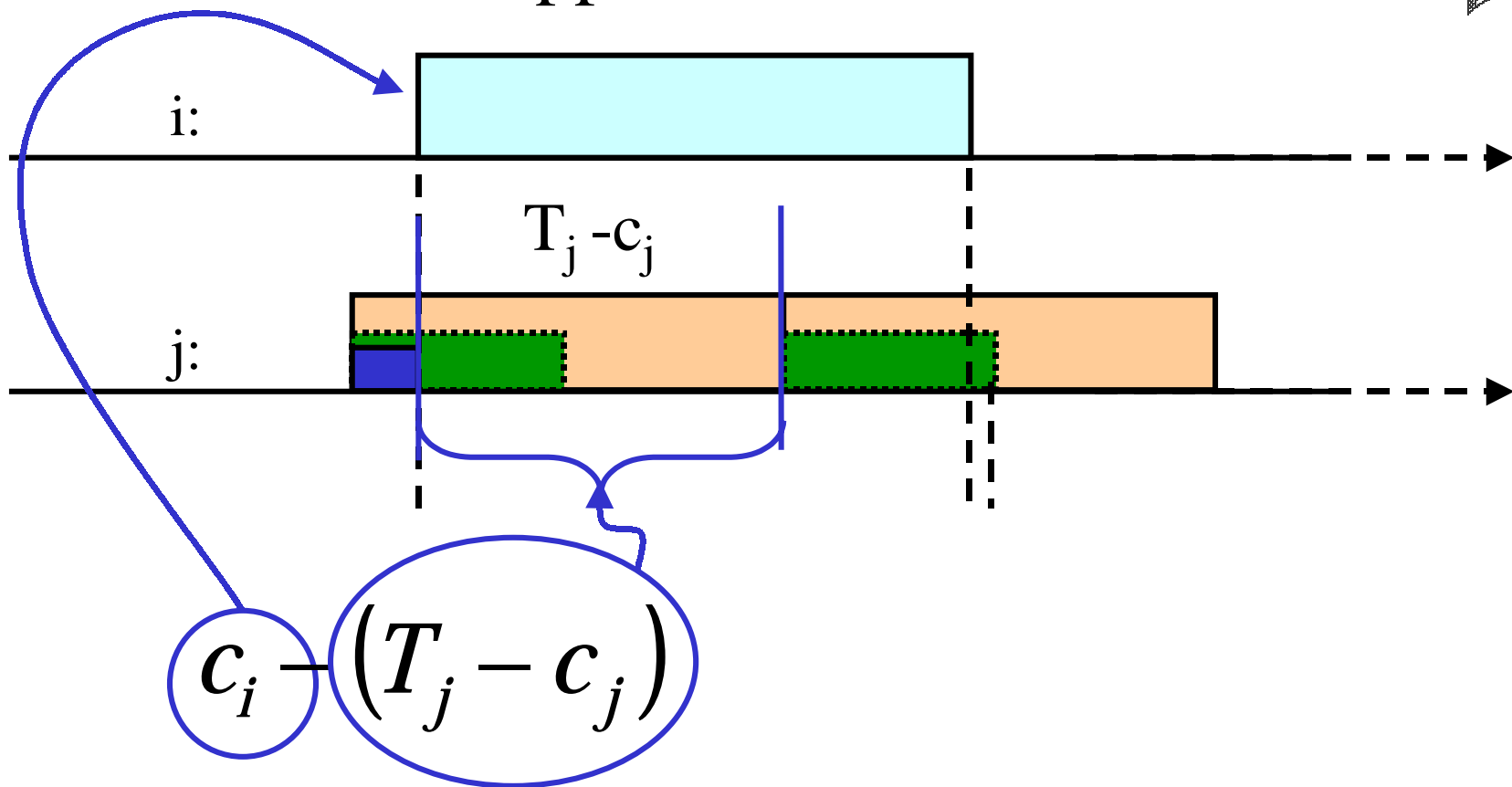
Offset between jobs invocations



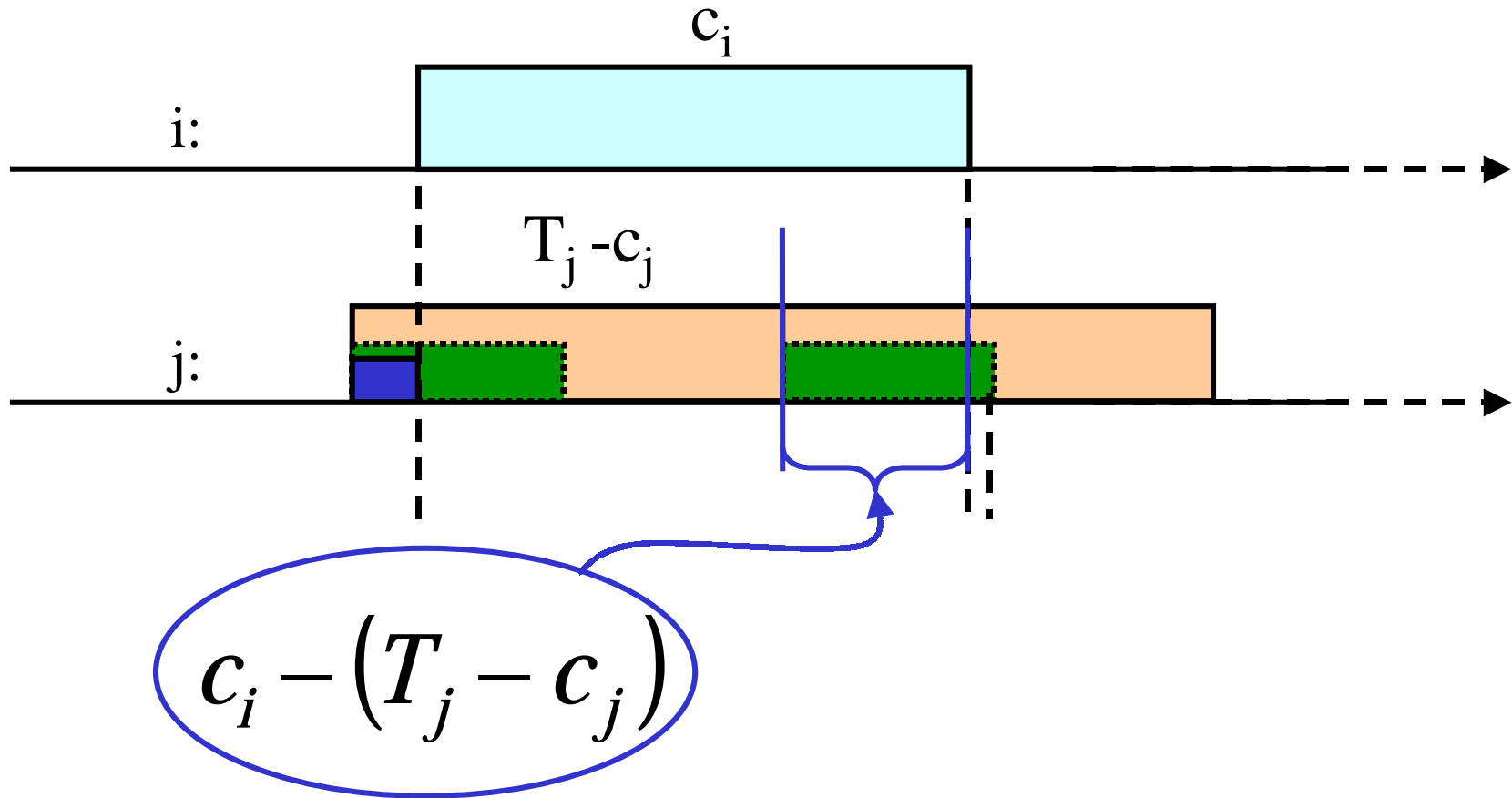
When happens 1 deadline miss



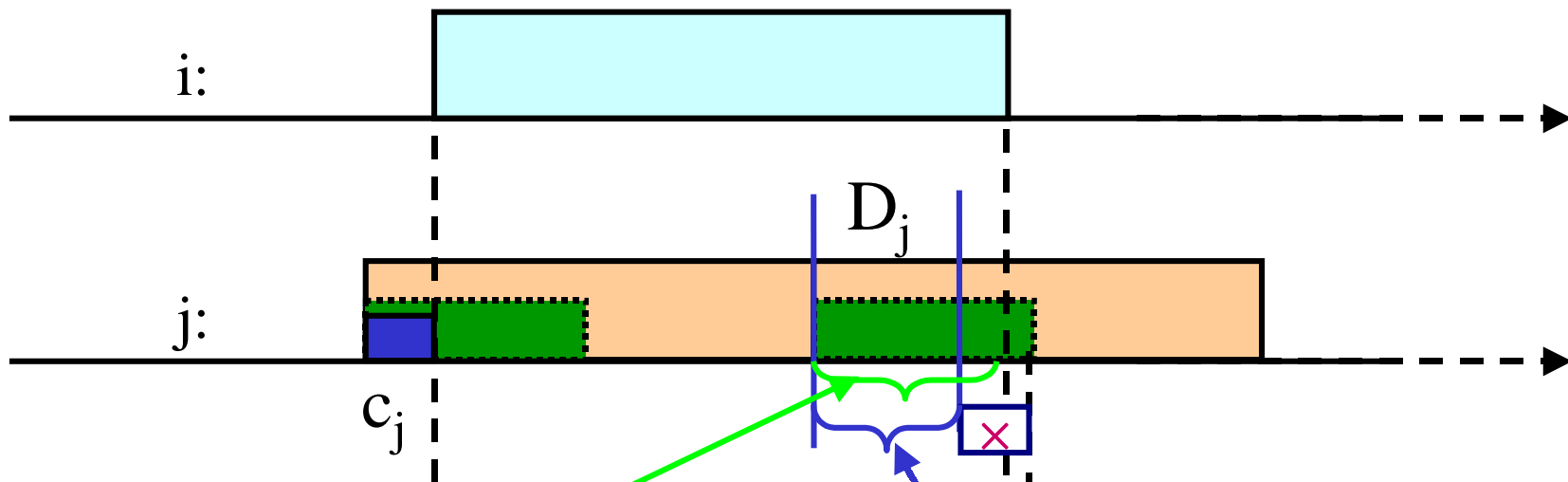
When happens 1 deadline miss



When happens 1 deadline miss

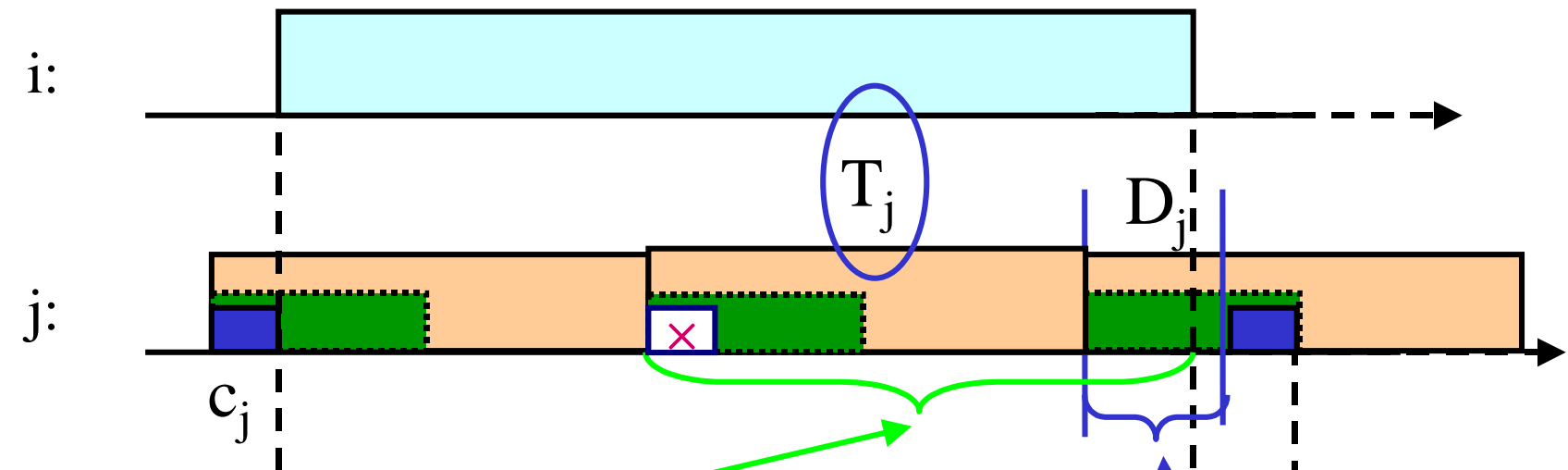


When happens 1 deadline miss



if $c_i - (T_j - c_j) > D_j - c_j$ then 1 miss in the best case.
i.e., at least 1 miss

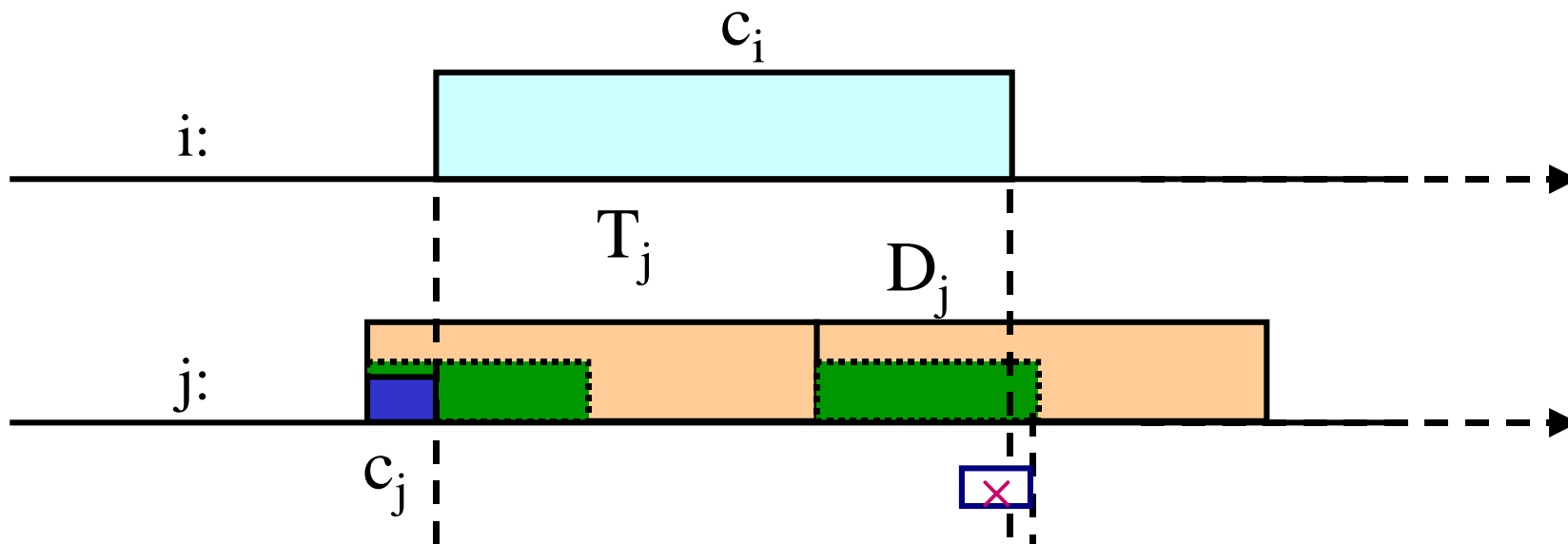
When happens 1 deadline miss



if
$$c_i - (T_j - c_j) \leq T_j + D_j - c_j$$

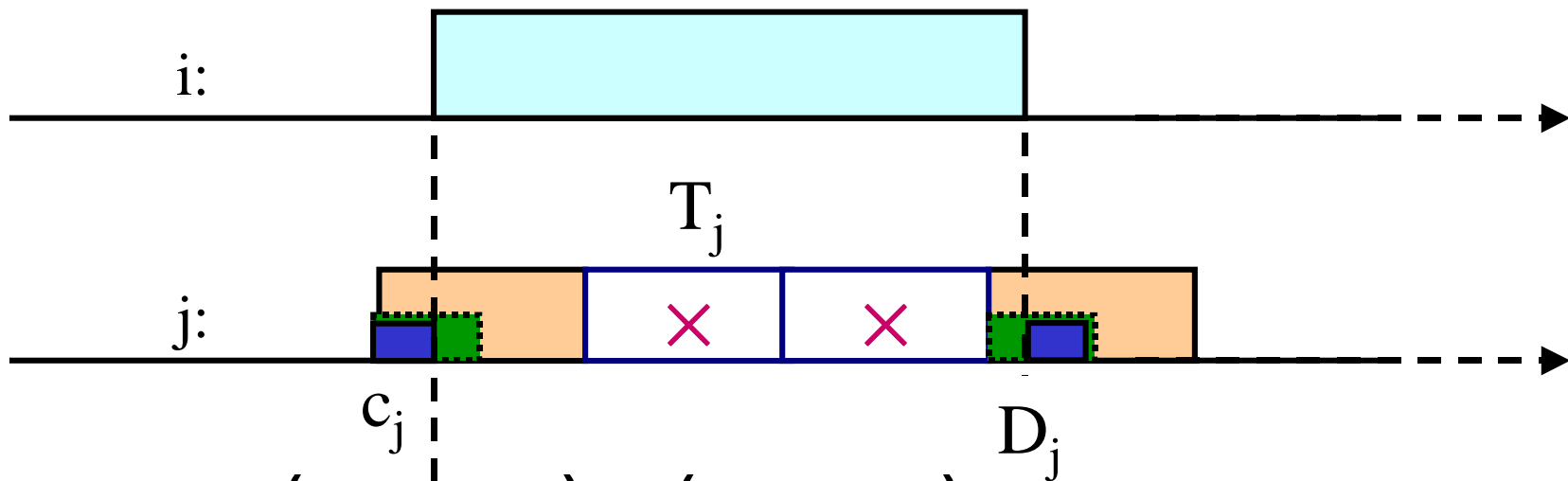
then no more than 1 miss

When happens 1 deadline miss



$$\left\{ \begin{array}{l} c_i - (T_j - c_j) > D_j - c_j, \\ c_i - (T_j - c_j) \leq T_j + D_j - c_j. \end{array} \right. \quad \begin{array}{l} \text{At least 1 miss} \\ \text{No more than} \\ \text{1 miss} \end{array}$$

Generalization to n deadline misses



$$\begin{cases} c_i - (T_j - c_j) > (n_{j,i} - 1) \cdot T_j + D_j - c_j, \\ c_i - (T_j - c_j) \leq n_{j,i} \cdot T_j + D_j - c_j. \end{cases}$$

which gives $x-1 \leq n < x$

Minimum number of deadline misses

$$n_{j,i} = \left\lceil \frac{c_i + 2c_j - D_j}{T_j} \right\rceil - 1.$$

Minimum number of jobs that stream j misses while a job of stream i is being served

$$M = \begin{bmatrix} \cdot & \cdot & \cdot & \cdot \\ n_{j,i} & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot \end{bmatrix} \quad \left. \vphantom{\begin{bmatrix} \cdot & \cdot & \cdot & \cdot \\ n_{j,i} & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot \end{bmatrix}} \right\} N \times N$$

Necessary conditions

Necessary Load condition

$$\sum_{i=1}^N \left[\frac{c_i}{T_i} \frac{m_i}{k_i} \right] \leq 1$$

Mutual feasibility condition

$$\forall i, j \leq N,$$

$$n_{i,j} \leq k_i - m_i$$

New
Necessary
Condition

Matrix-DBP

| | (m, k) | Execution time | Period Deadline | Initial μ -pattern | Priority |
|-------------|--------|----------------|--------------------|------------------------|----------|
| Stream a | (4, 5) | 15ms | 30ms | 01111 | 2 |
| Stream b | (2, 5) | 2ms | 5ms | 00101 | 3 |

$$M = \begin{bmatrix} 0 & 0 \\ 2 & 0 \end{bmatrix}$$

$$\text{Priority}_{a,b} = \text{DBP}_a - n_{a,b} = 2$$

$$\text{Priority}_{b,a} = \text{DBP}_b - n_{b,a} = 1$$



Simulation scenario

| | (m,k)- constraints | Job Process time: c_i | Period (T_i)/ Deadline(D_i) |
|-----------------|-------------------------------|---|--|
| Stream 0 | (2,5) | 8/c | 12 |
| Stream 1 | (4,5) | 10/c | 20 |
| Stream 2 | (3,6) | 2/c | 5 |
| Stream 3 | (1,5) | 4/c | 6 |

Matrix of the scenario

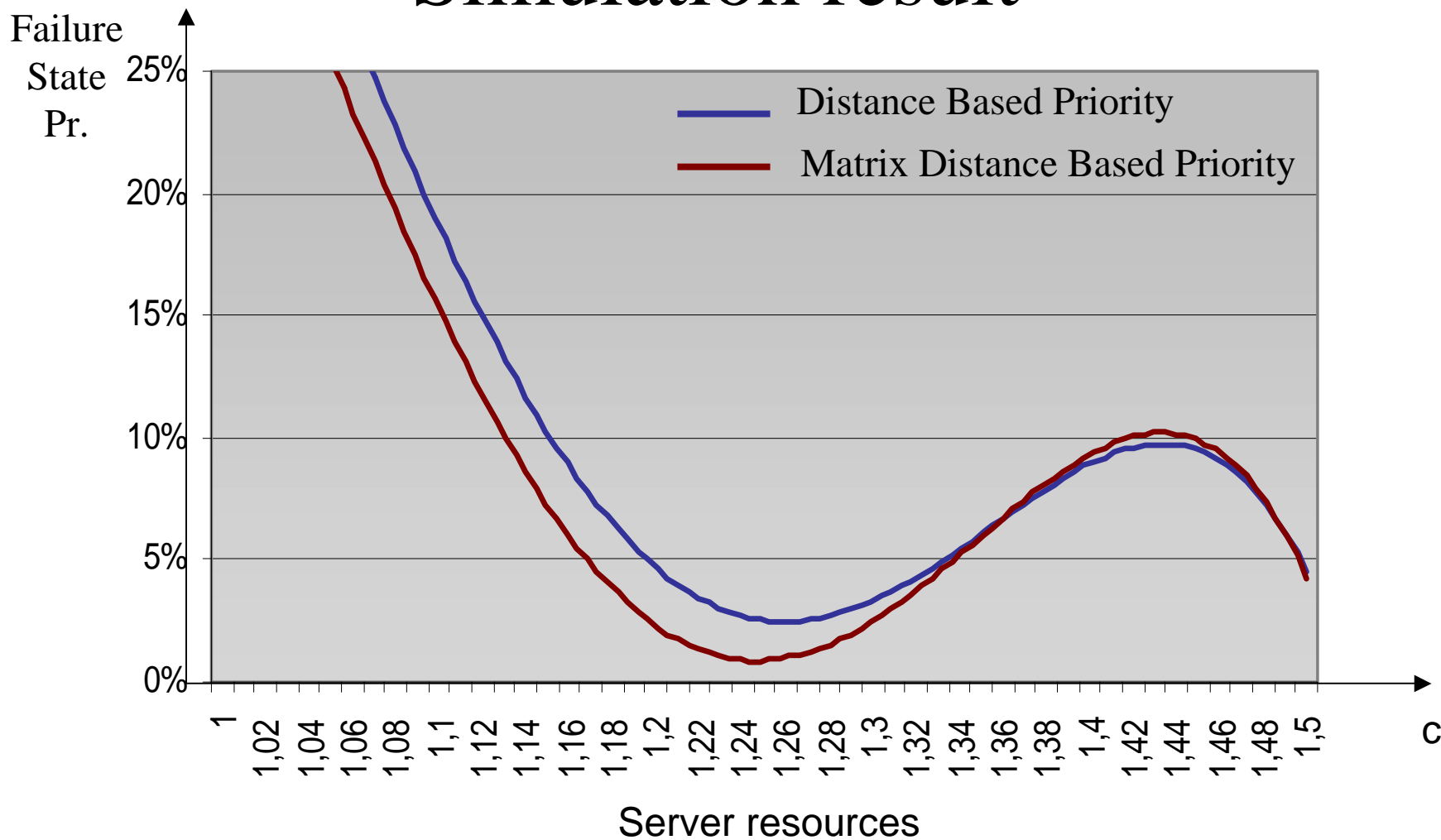
- When $c = 1$

$$M = \begin{bmatrix} 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 1 & 1 & 0 & 0 \\ 1 & 1 & 0 & 0 \end{bmatrix}$$

- When $c = 1.5$
Matrix-DBP
becomes DBP

$$M = \begin{bmatrix} 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix}$$

Simulation result



Contributions on (m,k)-firm

- Pointed out the drawback of the classic DBP when it is applied to a more general real-time context
- Provided an additional necessary condition call mutual schedulability test
- Proposed matrix-DBP to correct DBP

Part 4: Future work

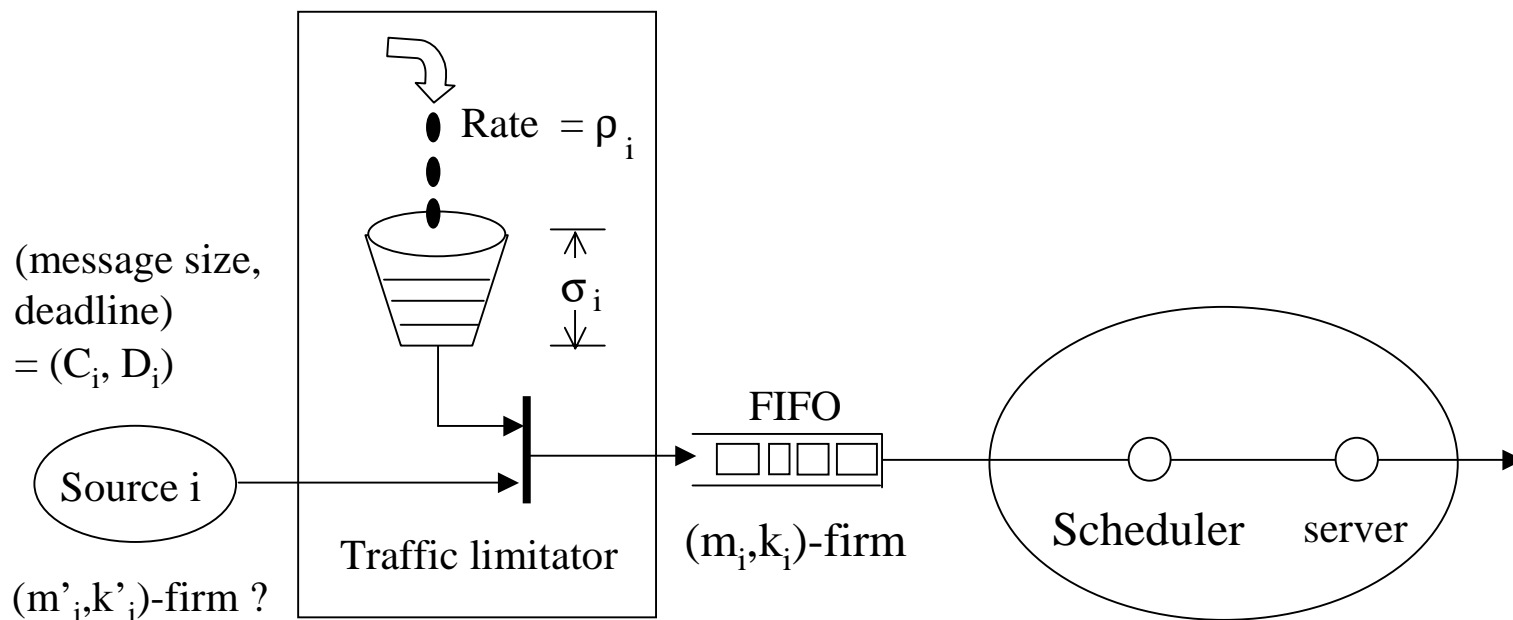


On Matrix-DBP for (m,k) -firm

- Analysis of necessary condition on c for (m,k) -firm guarantee (i.e. find the value of c from which the system always has \emptyset failure state)
- Taking other criteria than the global failure state percentage (e.g., fairness in failure state percentage for each stream)
- Extension to multi-hops case by taking global deadline and local deadlines

On (m,k) -firm

- Enhancement of DBP for aperiodic streams
- (m,k) -firm for a (σ, ρ) upper bounded traffic



Application domains of (m,k)-firm

- Handling real-time traffic in Switched Industrial Ethernet (an Intranet) and in Internet
- Evaluating dependability in process control systems (in which we suppose that the state variables are over-sampled vs. Nyquist frequency)

Questions and remarks?

