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

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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

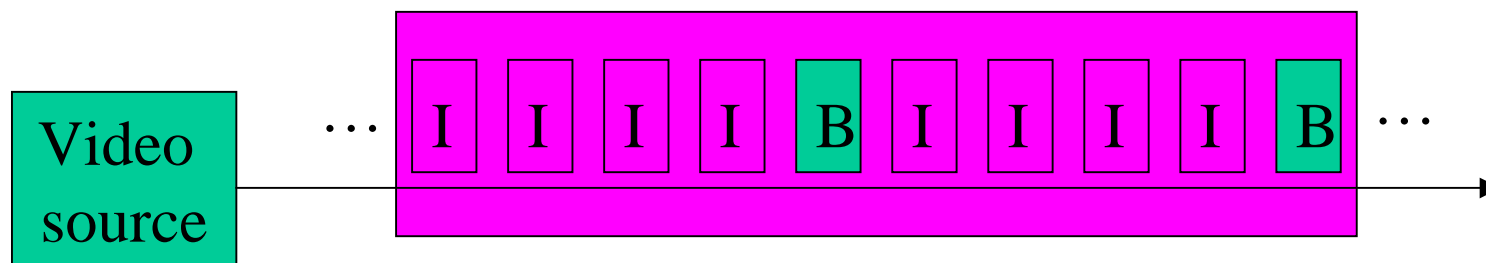


# Why we interest in (m,k)-firm?

- HRT uses WC analysis leading to oversized 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?

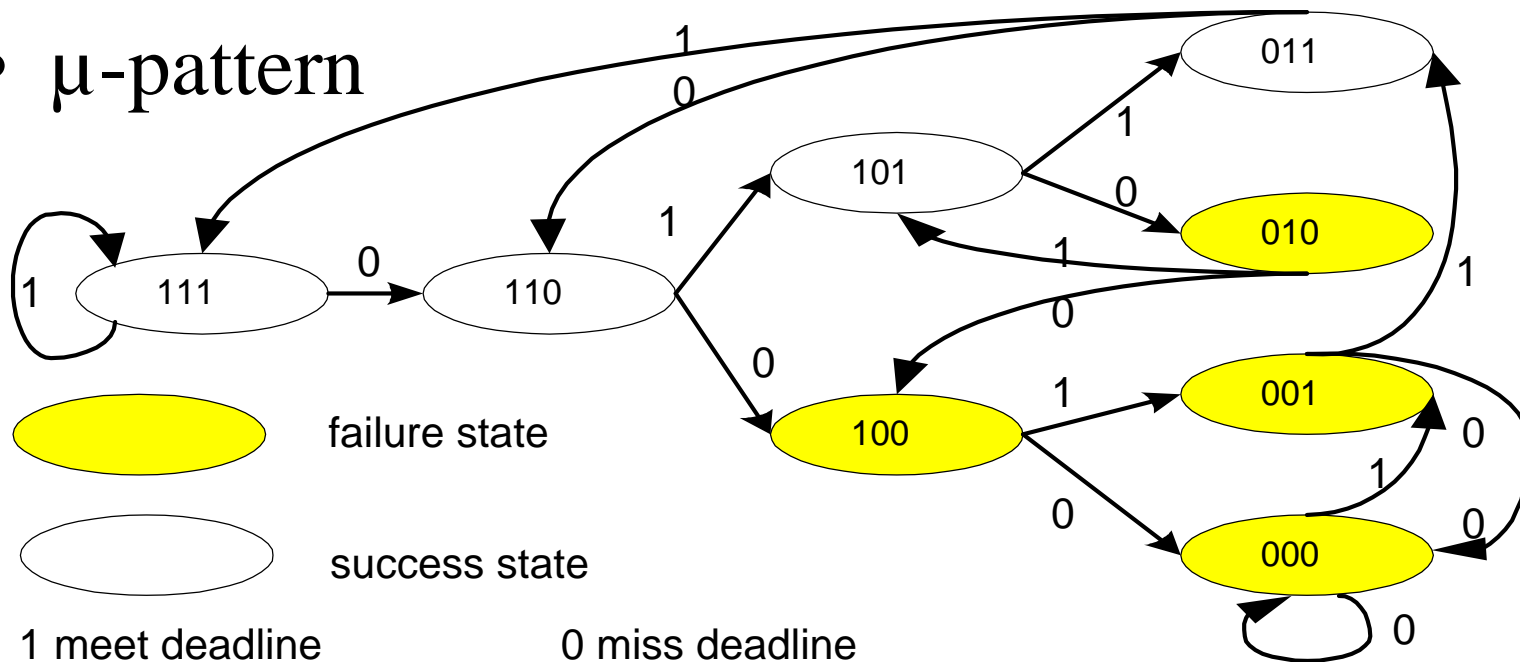
- (m,k)-firm guarantees the deadline meeting of  $m$  among any  $k$  consecutive task invocations or message transmissions
- (m,k)-firm provides a general frame for RT constraints description :
  - HRT is a particular case of (m,k)-firm with  $m=k$
  - SRT guarantee with probability  $p = m/k$  is a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

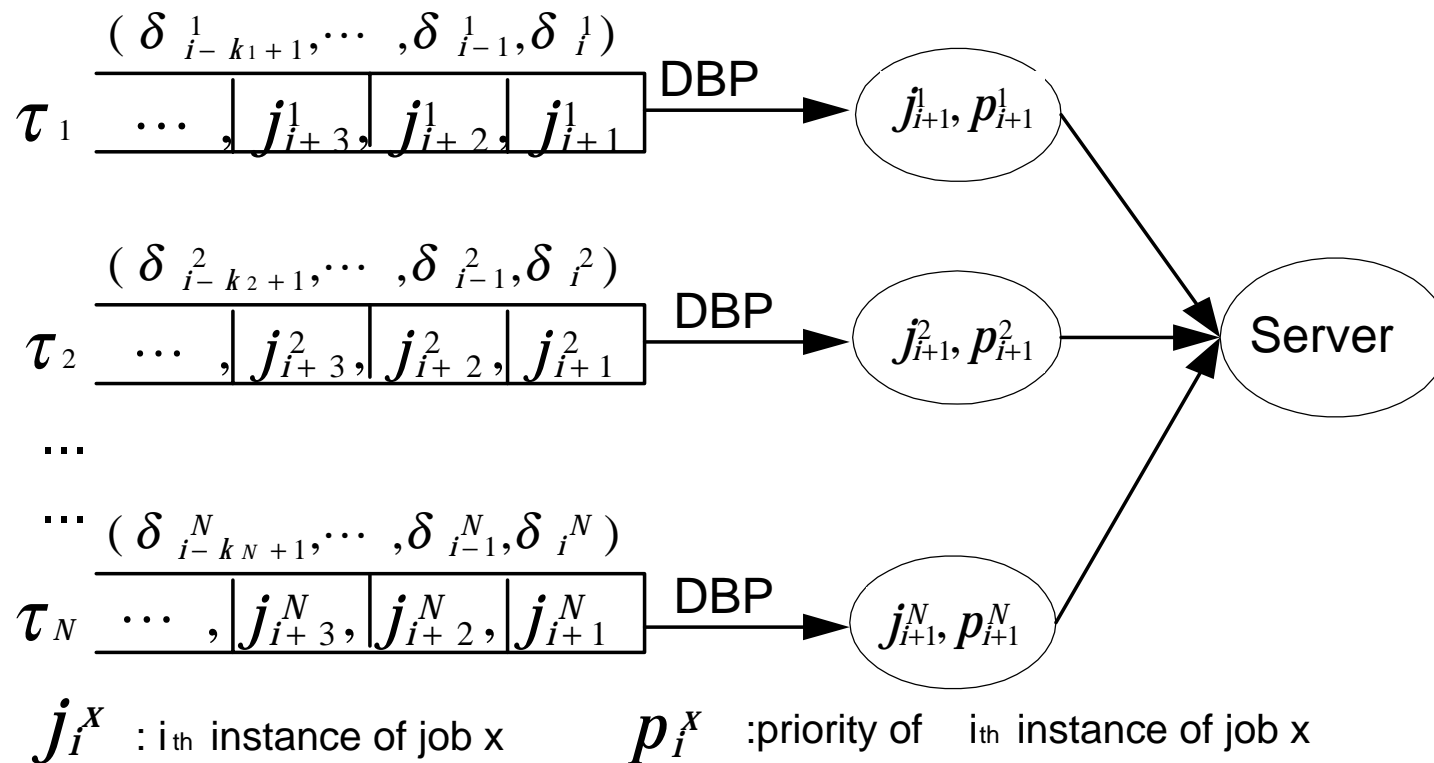




# DBP: Distance Based Priority

- DBP of a  $\mu$ -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.:

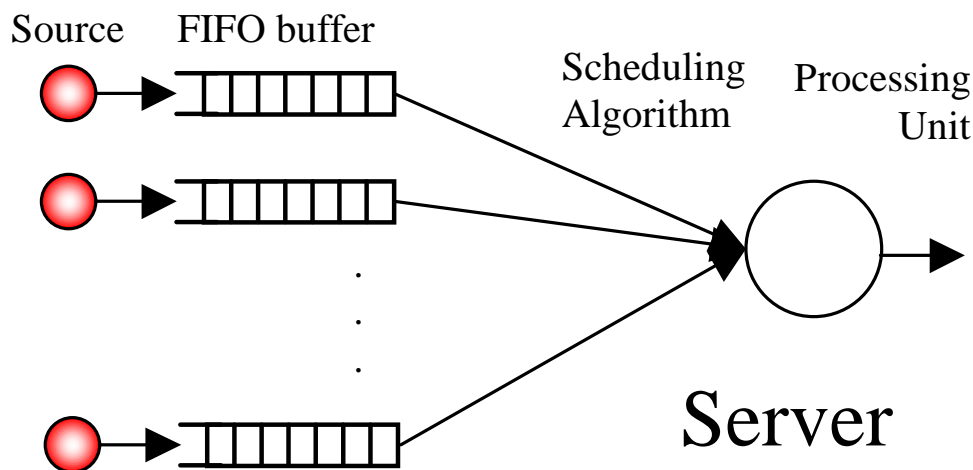
$$\sum_{i=1}^N \left[ \frac{c_i}{T_i} \frac{m_i}{k_i} \right] \leq 1 \quad \text{instead of} \quad \sum_{i=1}^N \left[ \frac{c_i}{T_i} \right] \leq 1$$

- 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



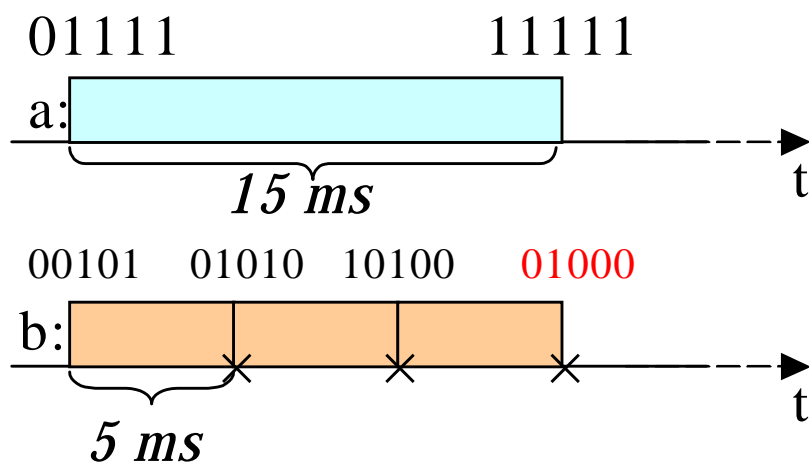
- A job is modeled by:  $\tau_i = \{T_i, D_i, c_i, m_i, k_i\}$
- Pb1: how to choose when several jobs have the same priority? (DBP+EDF?)
- Pb2: how to take into account the relative importance among jobs of all sources ?

# Un example of Pb2

	(m,k)-constraint	Service time (ms)	Period/Deadline	Initial $\mu$ -pattern
<b>Sa</b>	(4,5)	15	30	{01111}
<b>Sb</b>	(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



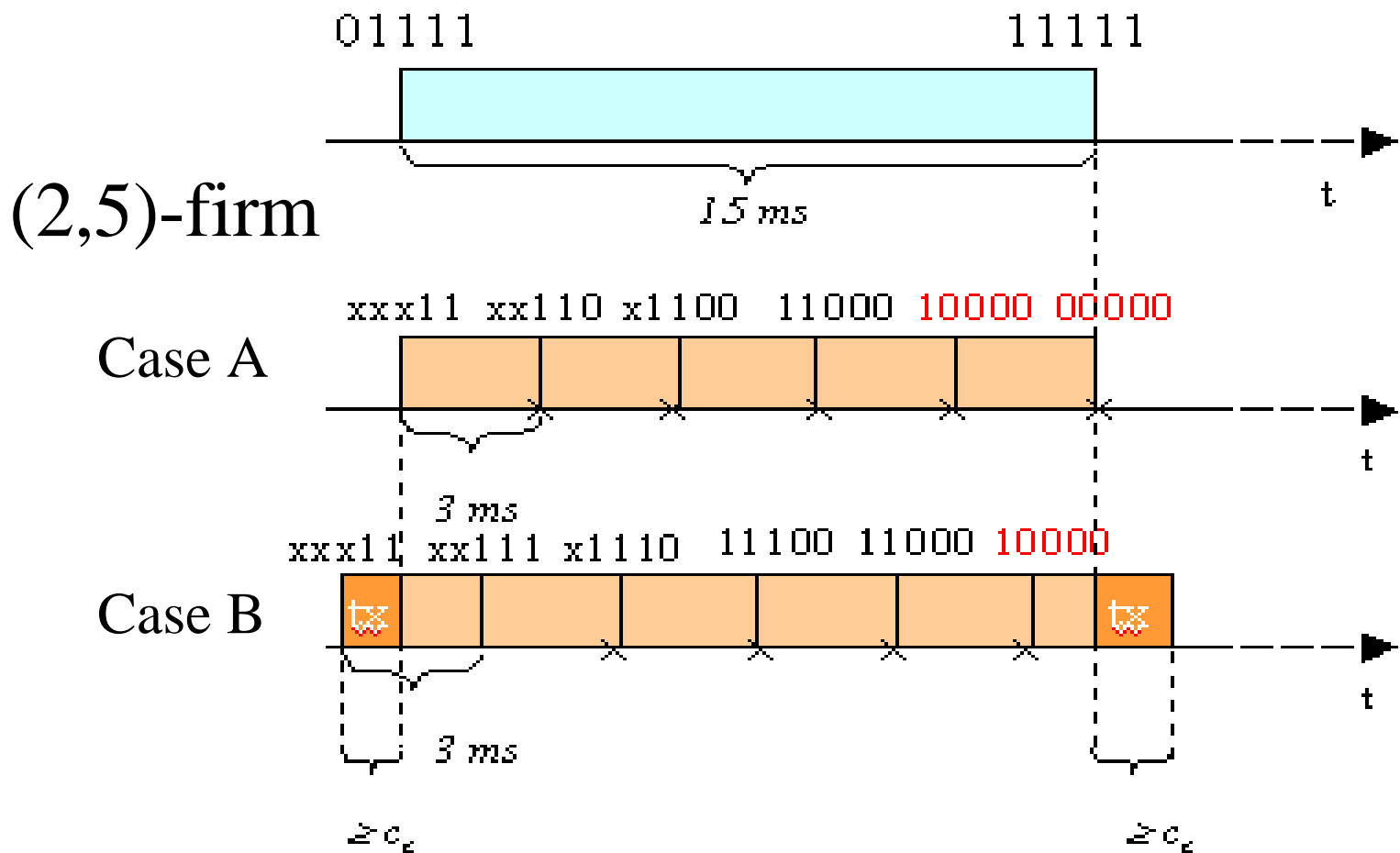
*Matrix-DBP can meet all these requirements*

# Part 3: Matrix-DBP

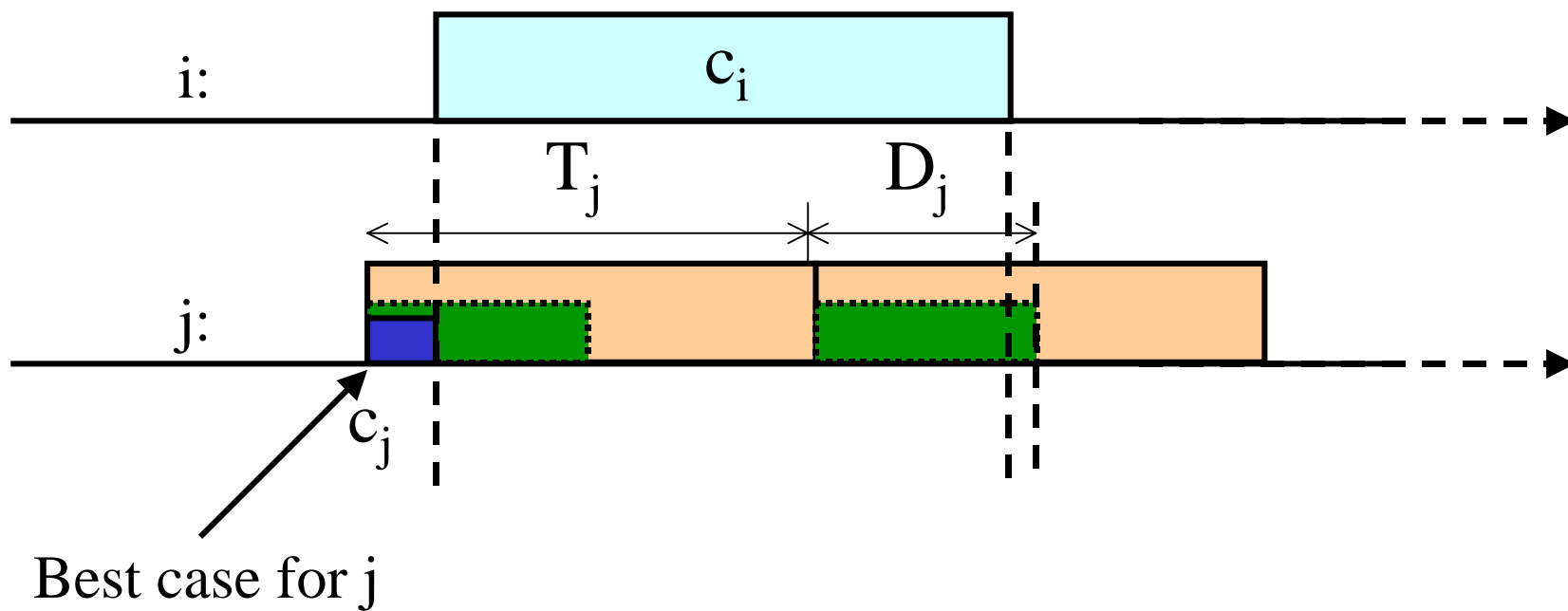




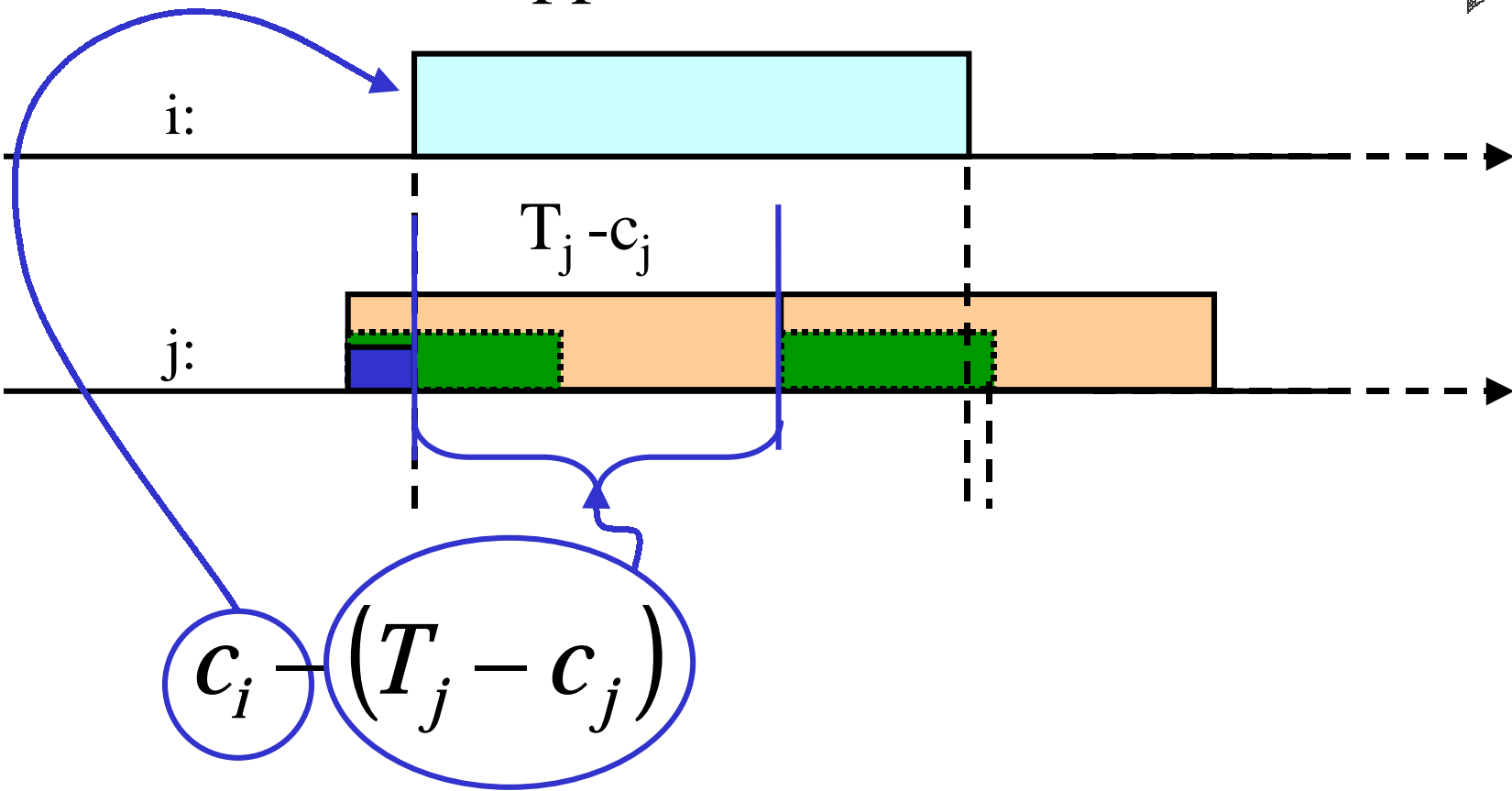
# Offset between jobs invocations



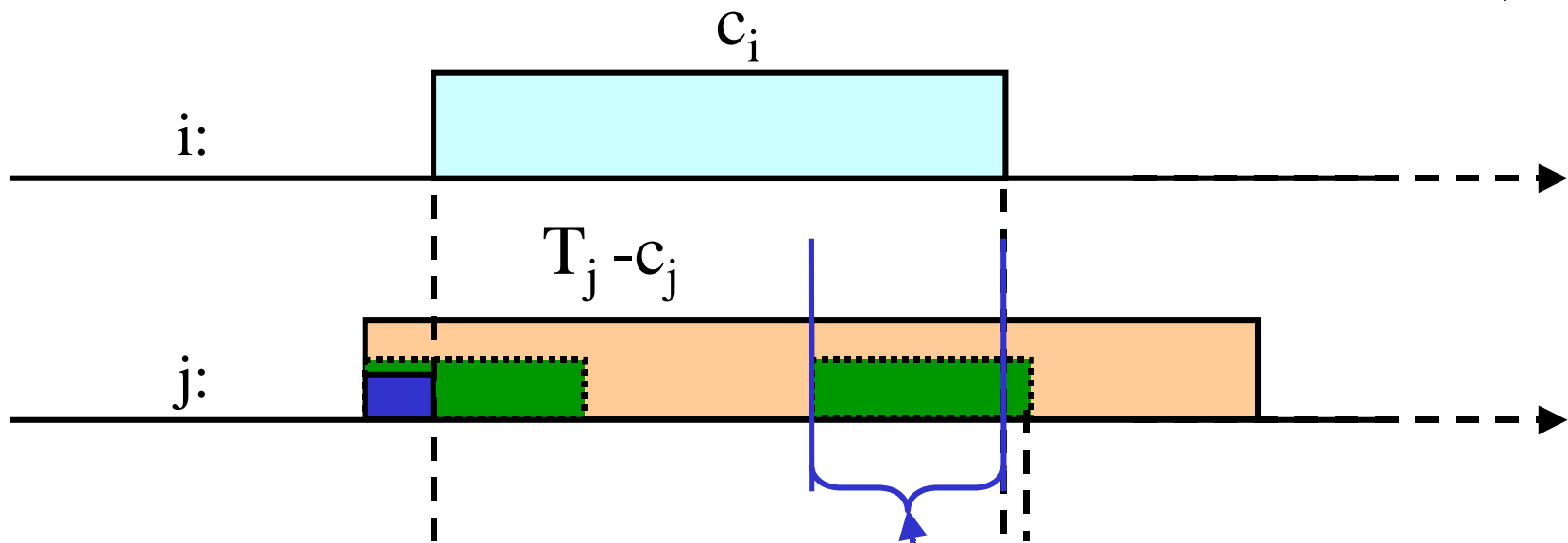
# When happens 1 deadline miss



# When happens 1 deadline miss

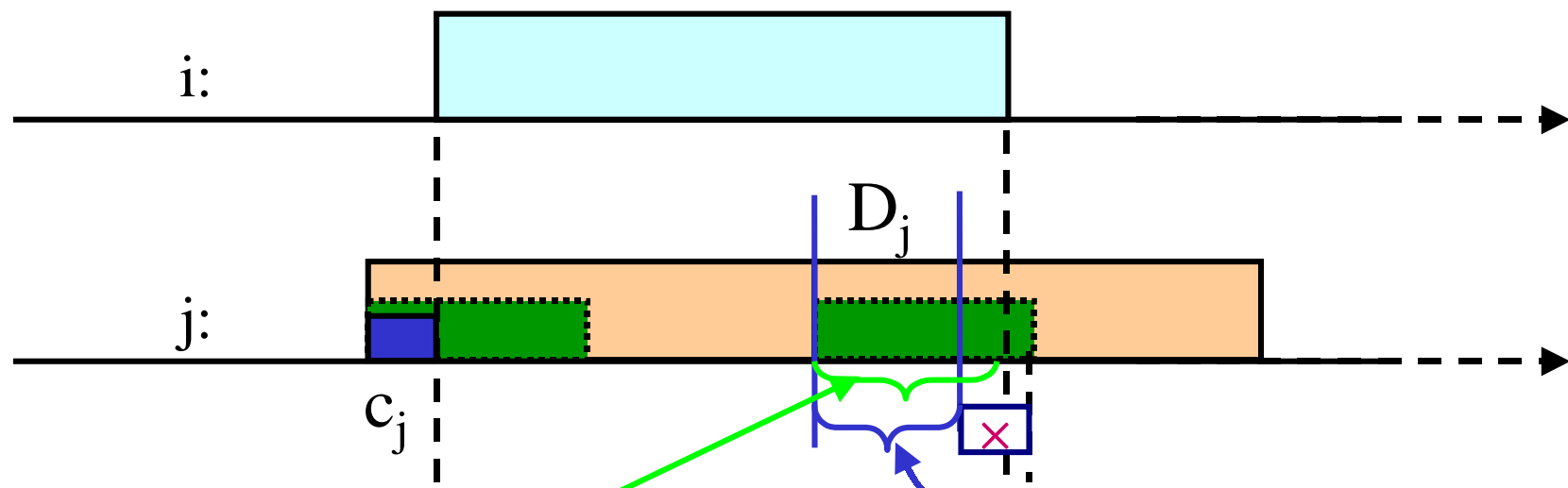


# When happens 1 deadline miss



$$c_i - (T_j - c_j)$$

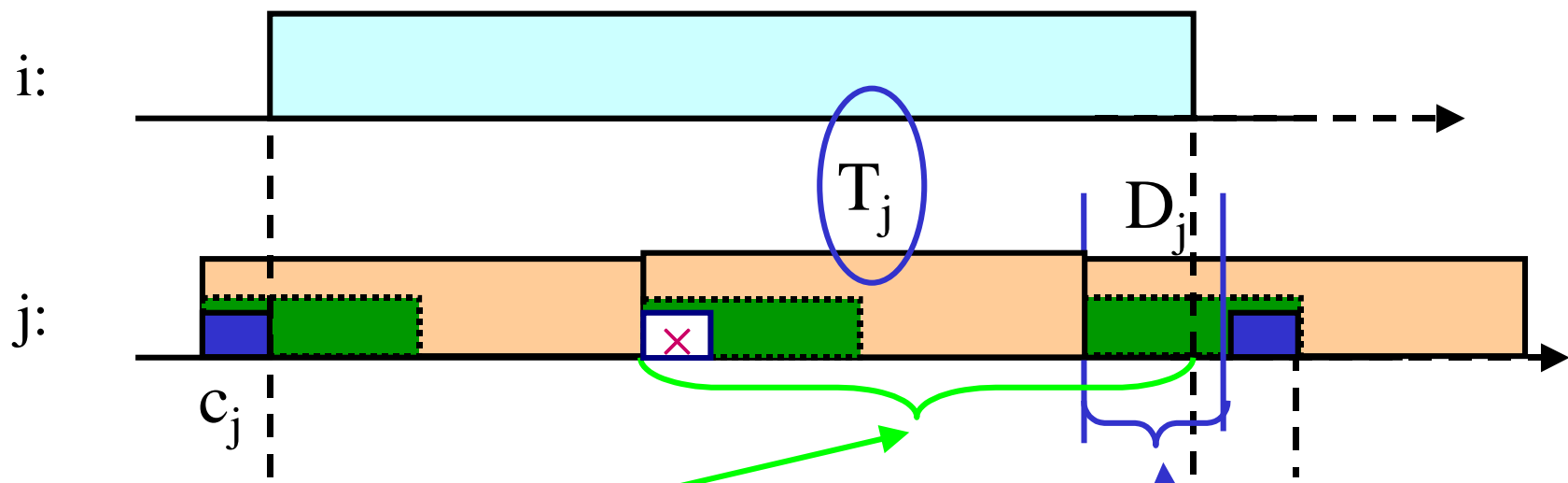
# When happens 1 deadline miss



if  $c_i - (T_j - c_j) > D_j - c_j$  then 1 miss in the best case.

i.e., at least 1 miss

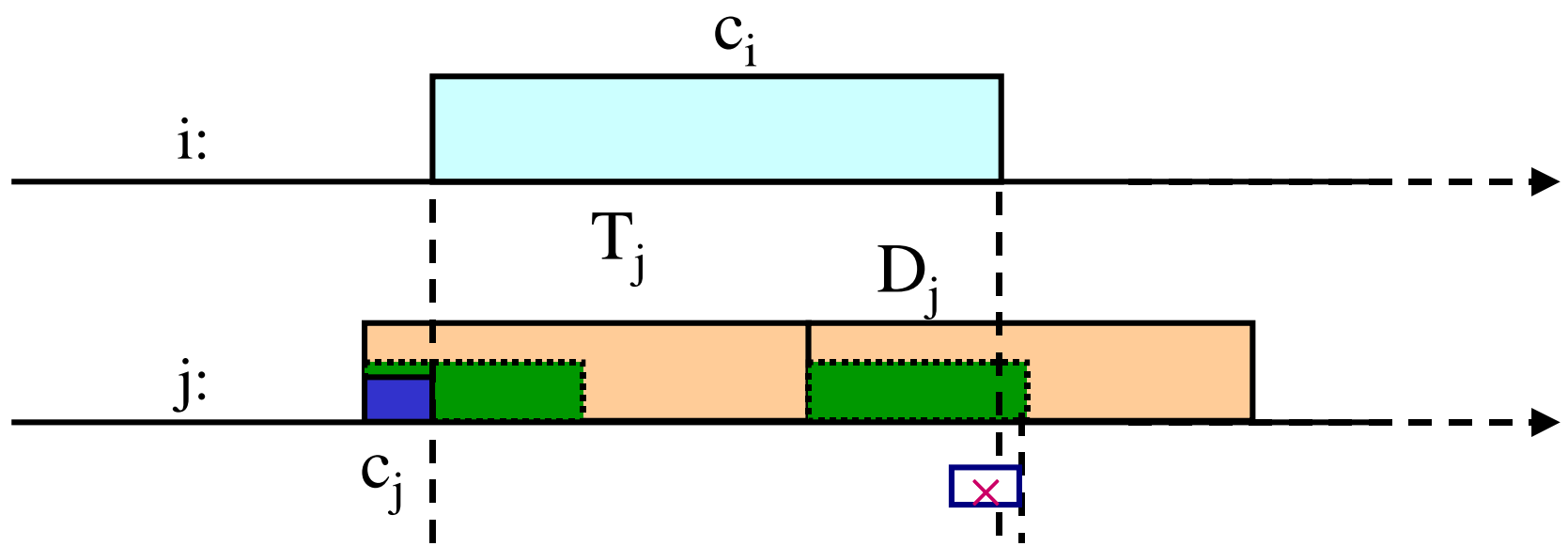
# When happens 1 deadline miss



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

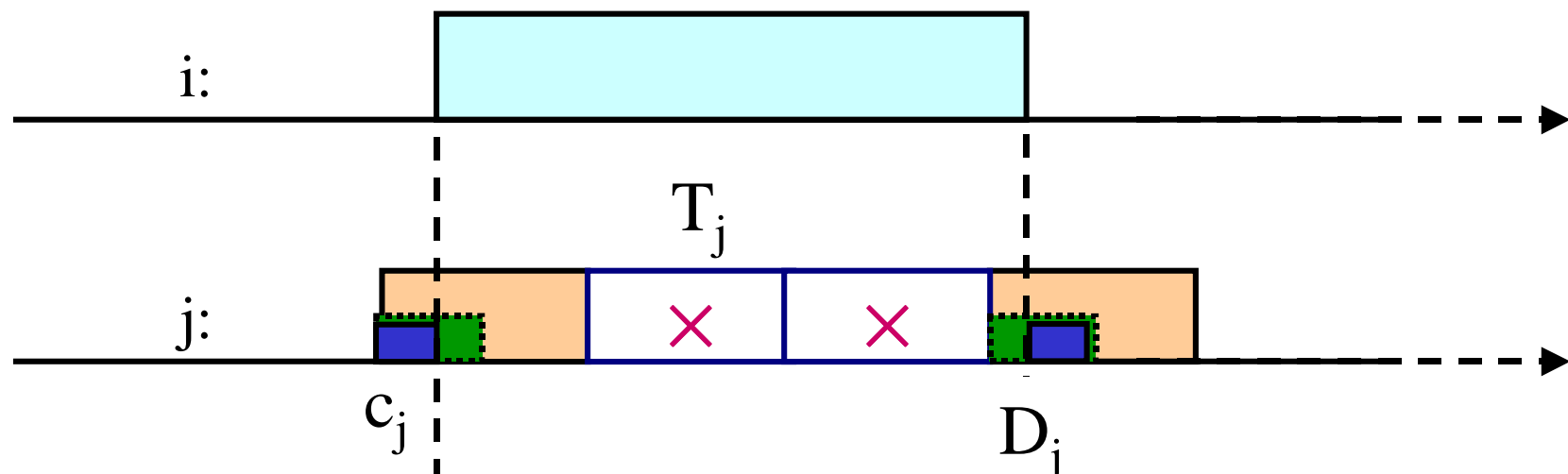
then no more than 1 miss

# When happens 1 deadline miss



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

# Generalization to $n$ deadline misses



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

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

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

# 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 $\mu$ -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

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

# Matrix of the scenario

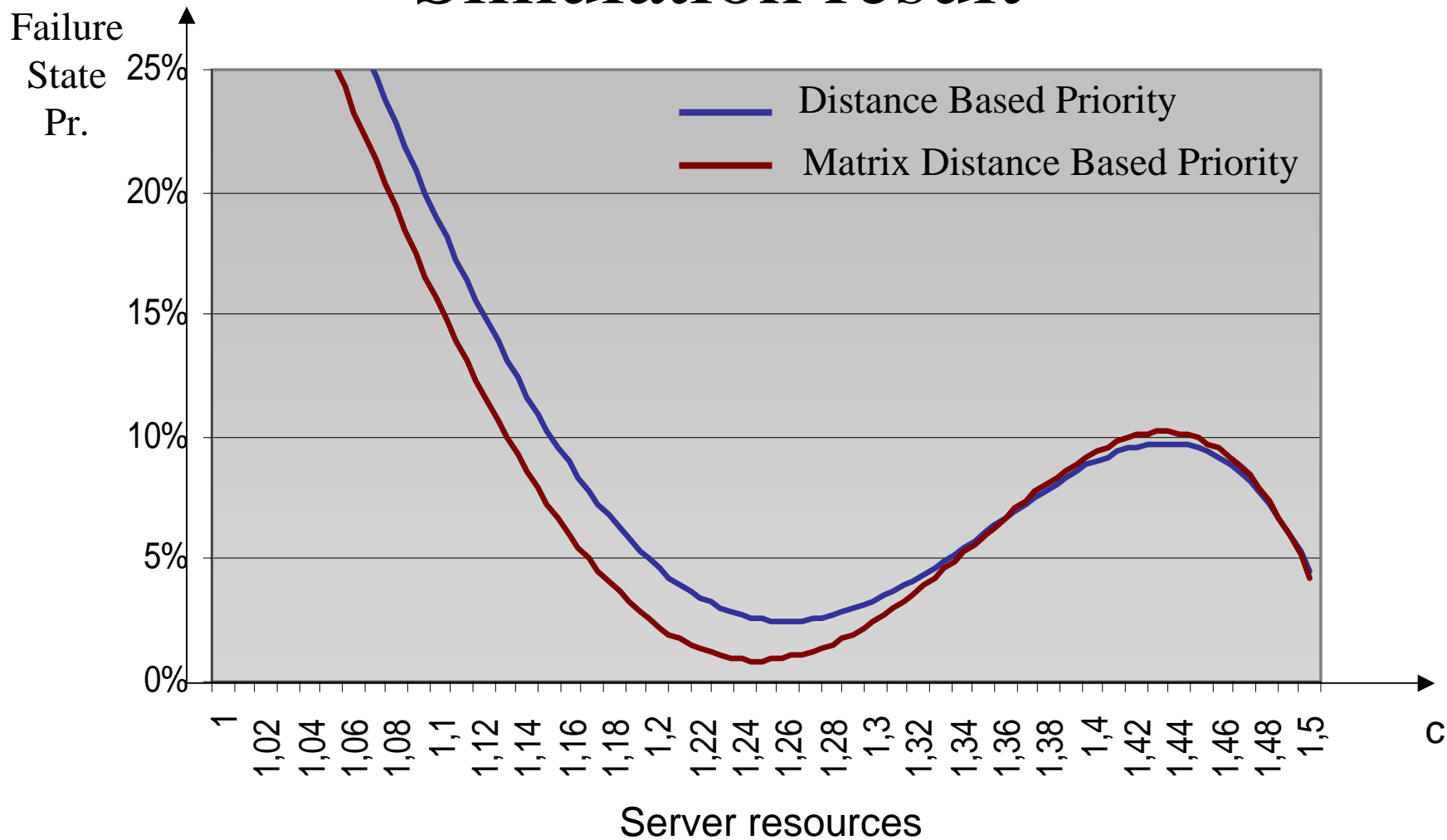
- When  $c = 1$

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

- 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



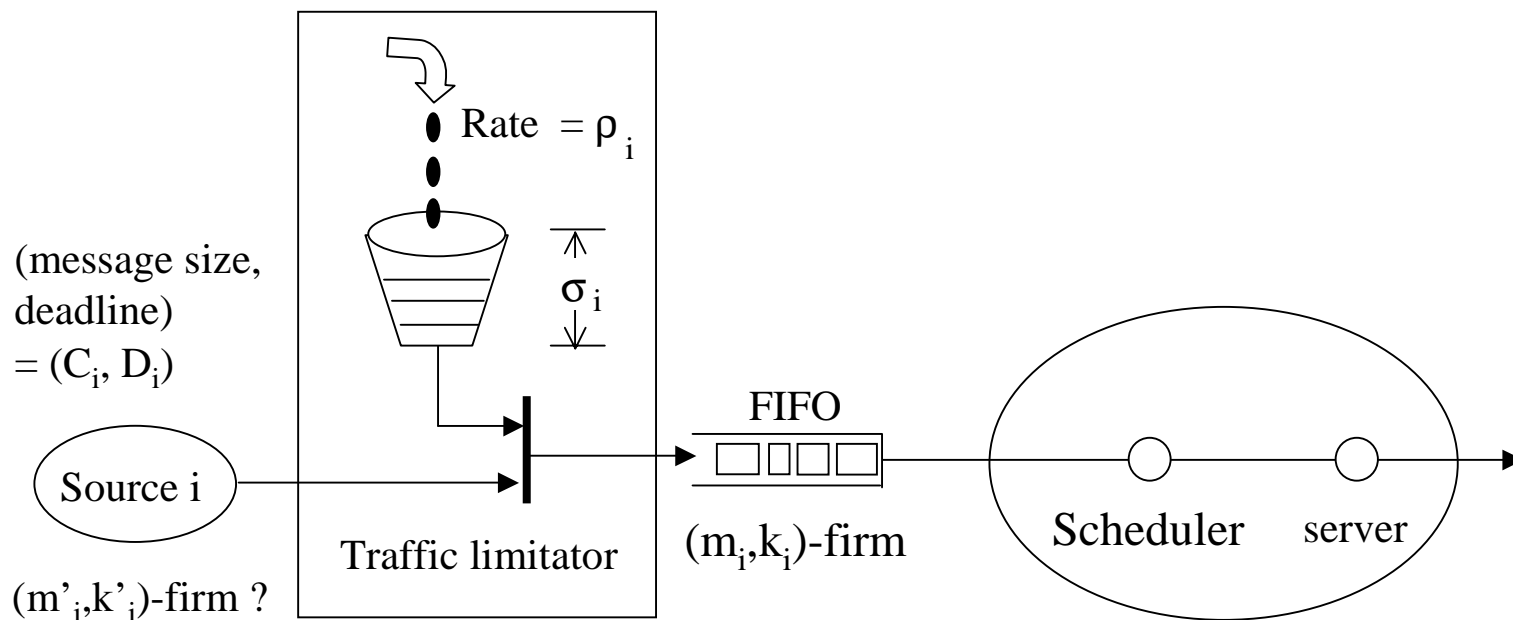


# On Matrix-DBP for $(m,k)$ -firm

- 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  $(\sigma, \rho)$  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?

