Network Coding for Content Distribution

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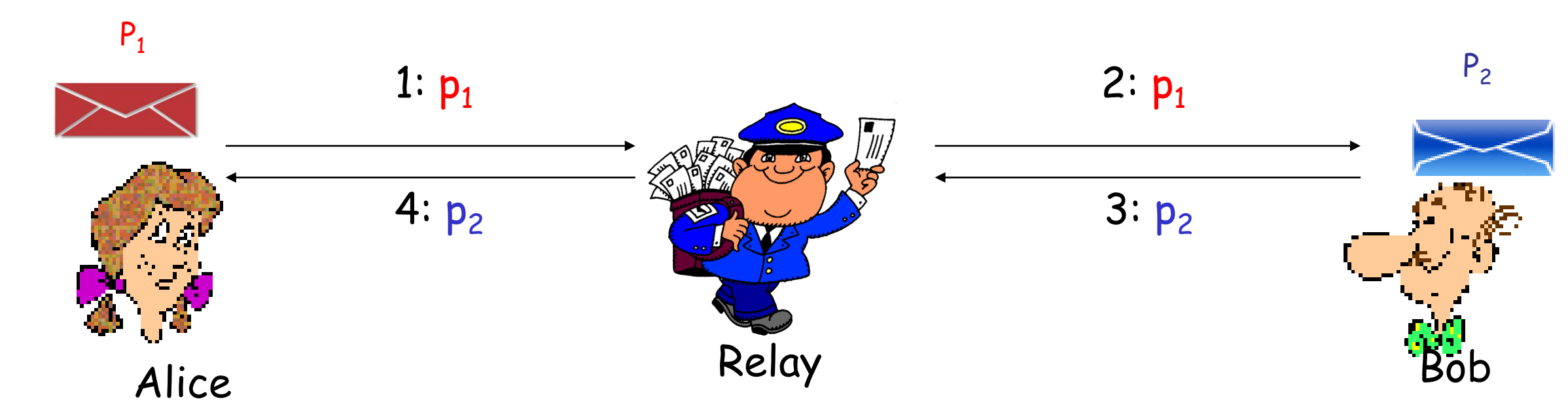
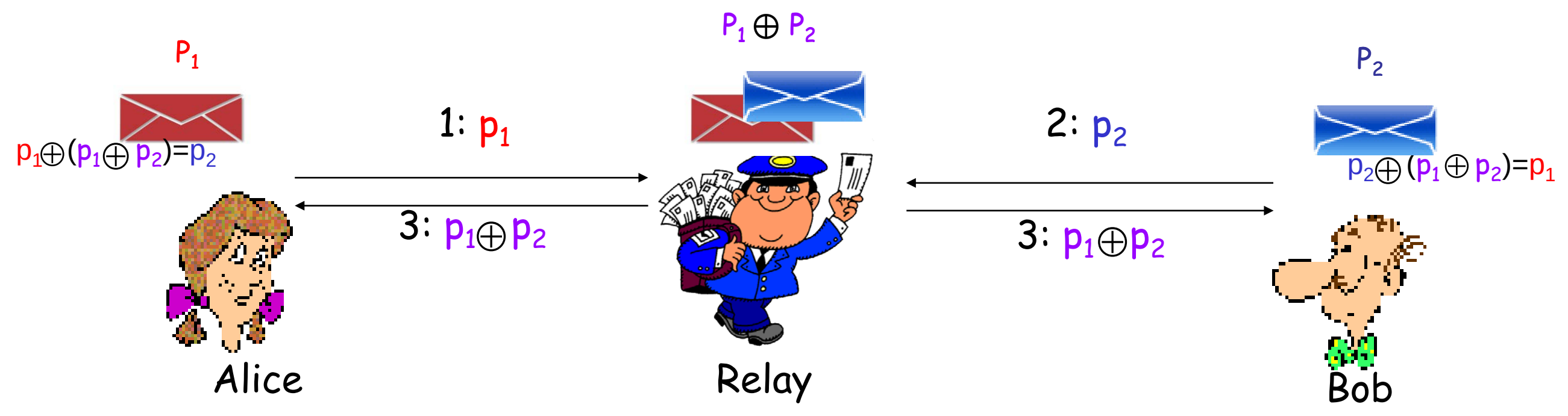
Research Opportunity:
Develop mobile application (on smart phone or tablet) to demonstrate real-time multimedia content distribution and distributed cloud storage with advanced network coding techniques.
Students with strong programming skills (especially with iOS or Android experience) are encouraged to apply.

I. Network Coding Gain in Throughput for Wireless Networks

❑ Traditional transmission without network coding



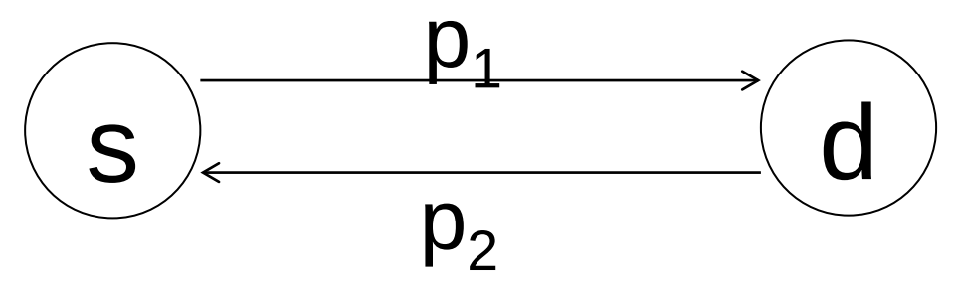
❑ Transmission with network coding



➡ Network coding decreases the number of transmissions from four to three

II. Network Coding Gain in Reliability for Lossy Wireless Networks

❑ Node *s* sends *n* packets to destination d via a unreliable wireless link



p_1: packet reception probability on link (*s*,*d*)
p_2: packet reception probability on link (*d*,*s*)

❑ The expected number of transmissions required with and without network coding

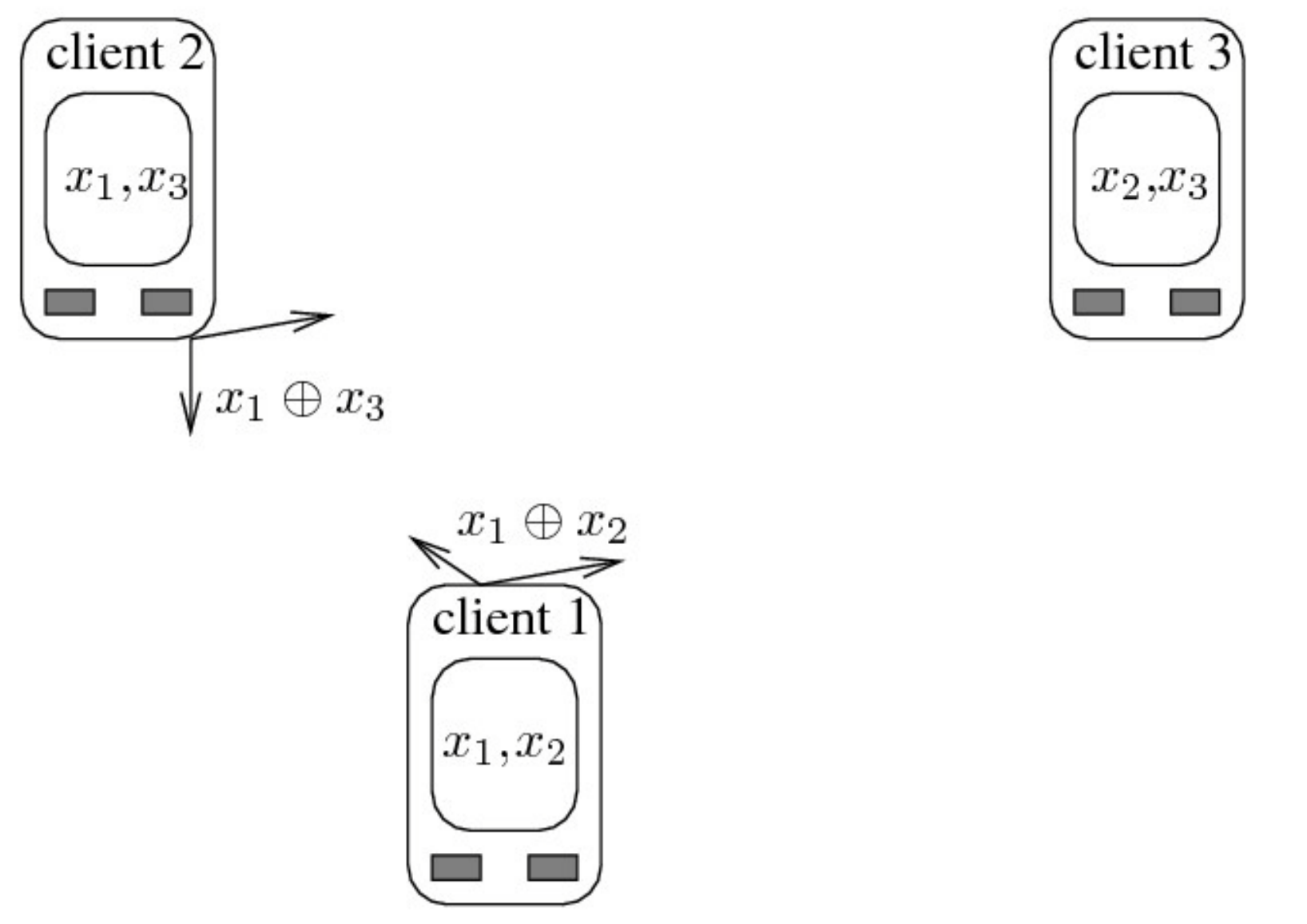
With network coding: $$\frac{n}{p_1}+\frac{1}{p_2}$$

Without network coding: $$\begin{cases} \frac{n}{p_1}+\frac{1}{p_2}\log_{1-p_1}\frac{1}{n}, & \text{if } p_1 \neq 1 \\ n+\frac{1}{p_2}, & \text{otherwise} \end{cases}$$

Expected Number of transmissions (n=10)	p_1=0.5 p_2=0.5	p_1=0.5 p_2=0.8	p_1=0.5 p_2=1.0	p_1=0.7 p_2=0.8	p_1=0.7 p_2=1.0
With NC	22	21.25	21	15.5357	15.2857
Without NC	26.658	24.1612	23.329	16.6763	16.1982

III. Delay Minimisation for Network Coded Cooperative Data Exchange

❑ Cooperative data exchange



Three mobile clients would like to exchange information.

1. Without network coding:
Each node exchange x_1, x_2, x_3, x_4 individually

2. With network coding:
Client 1 sends $x_1 \oplus x_2$
Client 2 sends $x_1 \oplus x_3$

❑ Problem Description

- Initially each client c_j has a subset of packets in X_j
- Each client has a set of possible transmission rates in T_j, with which a set of clients is within its transmission range

❑ Objective

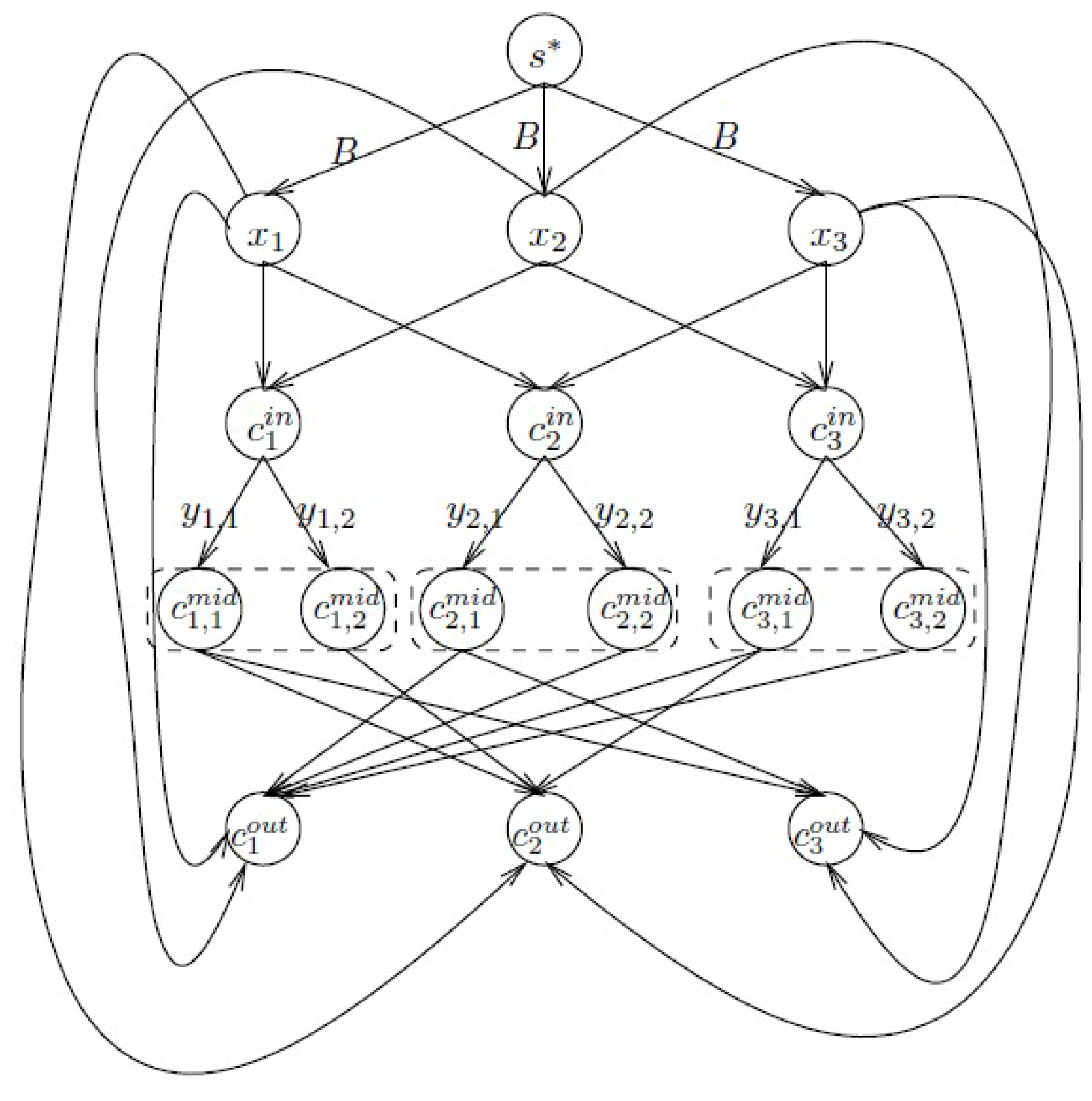
- Minimise the total data transmission delay such that each client has the whole packets in *X*

$$\min \sum_{j=1}^{m} \sum_{l=1}^{|T_j|} \frac{B y_{j,l}}{t_{j,l}}$$

B: packet size
$t_{j,l}$: the *l*-th transmission rate at client c_j
$y_{j,l}$: the number of transmissions with rate $t_{j,l}$ for client c_j

IV. Problem Solution

❑ With packet splitting, the problem can be formulated to a linear programming based on following auxiliary graph



❑ Without packet splitting, the minimum delay is bounded by

$$\gamma \le \min_{1\le j\le m}\{\sum_{x_i\in \overline{X_j}} \frac{B}{\max\limits_{j'\in\{j'|x_i\in X_{j'}\}}\{t^{x_i}{}_{j'}\}} + \sum_{l=1}^{|T_j|}\frac{B}{t_{j,l}}\xi_{j,l}\}$$

where

$$\xi_{j,l} = \begin{cases} \max\limits_{c_{j'}\in S^{j}{}_{1,2}} \{|\overline{X_{j'}}\cap X_j|\}, \text{ if } l=1 \\ \max\{\max\limits_{c_{j'}\in S^{j}{}_{l,l+1}} \{|\overline{X_{j'}}\cap X_j|\} - \sum\limits_{l'=1}^{l-1}\xi_{j,l'},0\}, \text{ if } l>1 \end{cases}$$

$$t^{x_i}{}_j = \max_l\{t_{j,l} \mid x_i \in \overline{X_{j'}} \text{ and } \forall c_{j'} \in N_{j,l} \text{ and } x_i \in X_j\}$$

$$S^j{}_{l_1,l_2} = \{c_{j'} \mid c_{j'} \in N_{j,l_1} - N_{j,l_2}\}$$

$N_{j,l}$: the set of clients within transmission range of *l*-th transmission rate at client c_j

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