Cost reduction on inter-datacenter delay tolerant network

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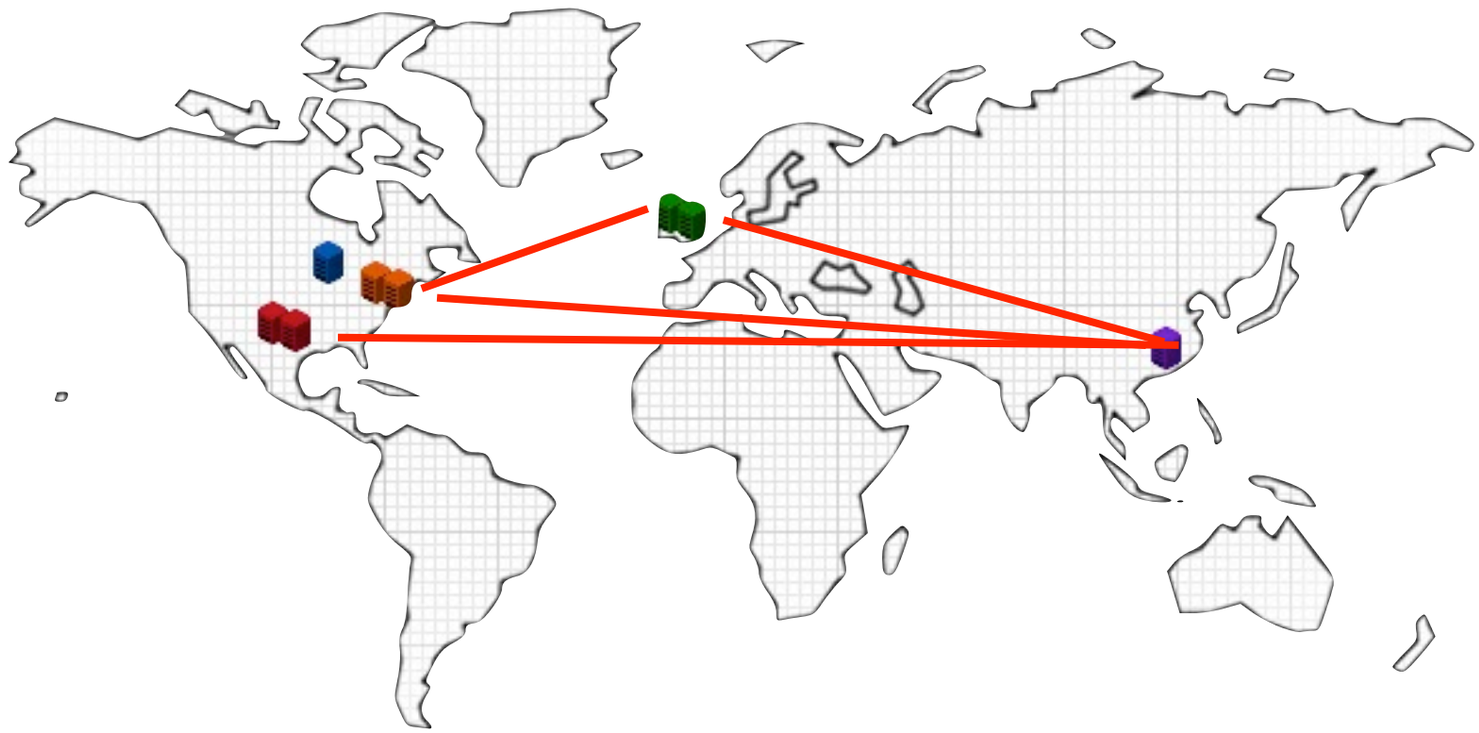
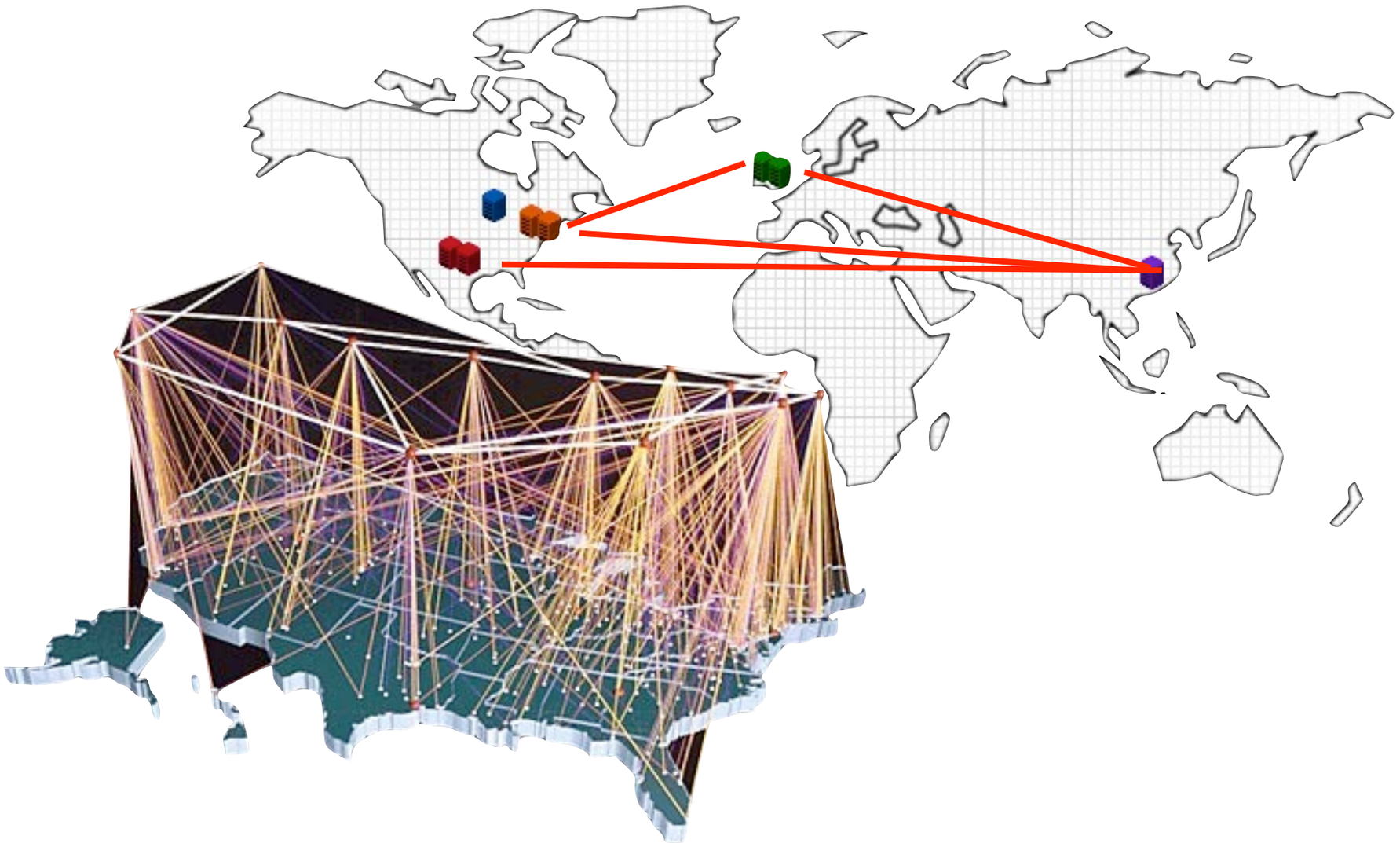
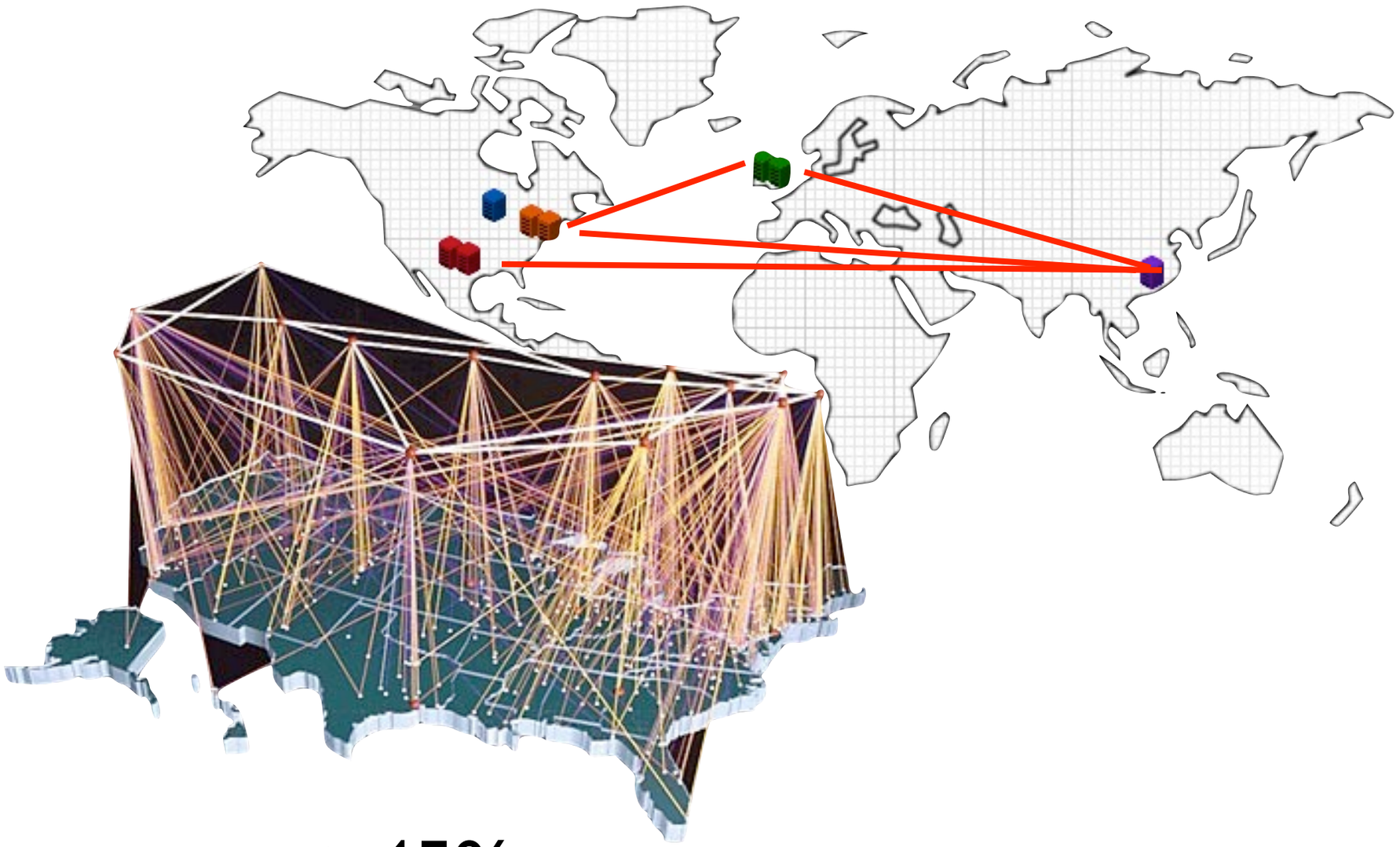
Friday, 25 January, 13







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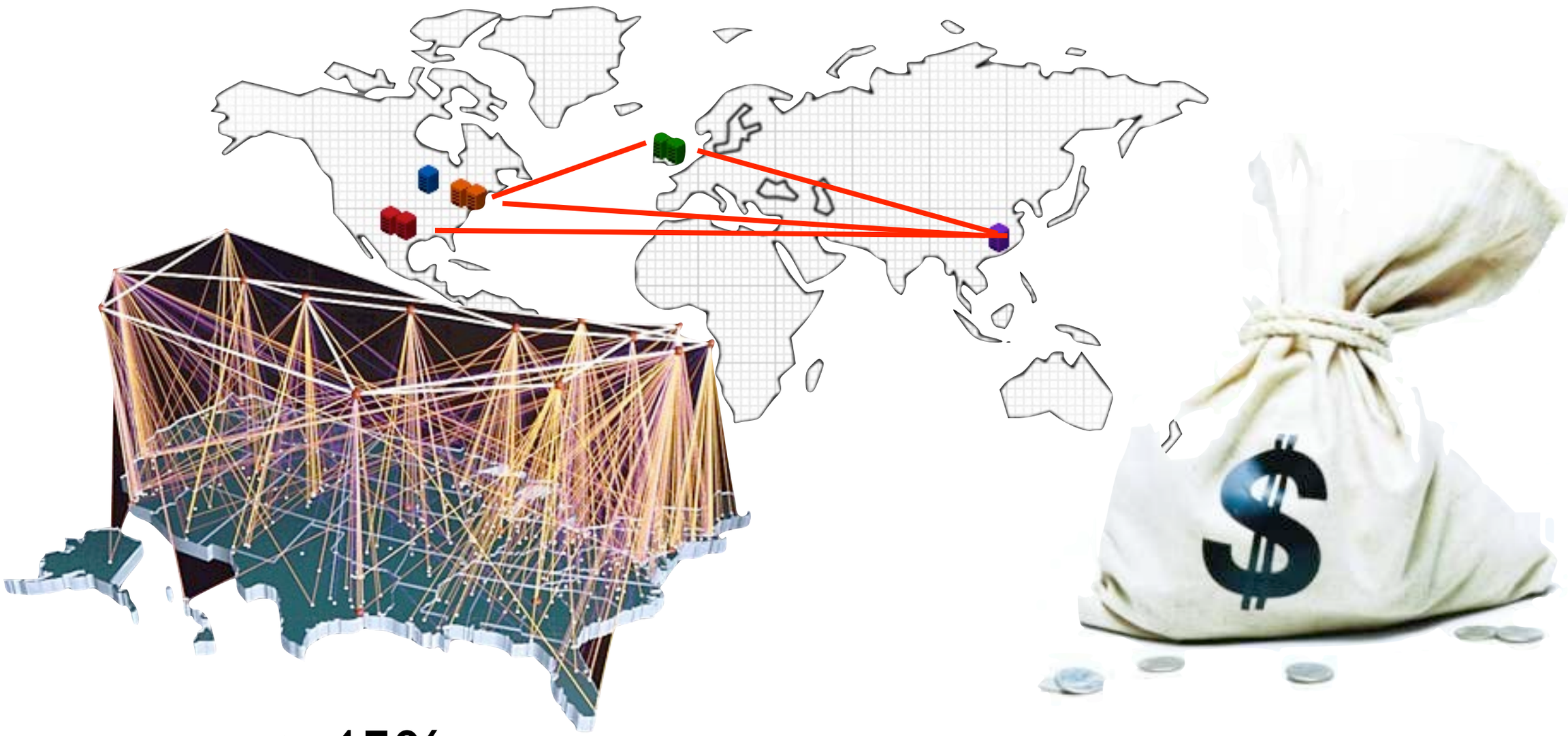

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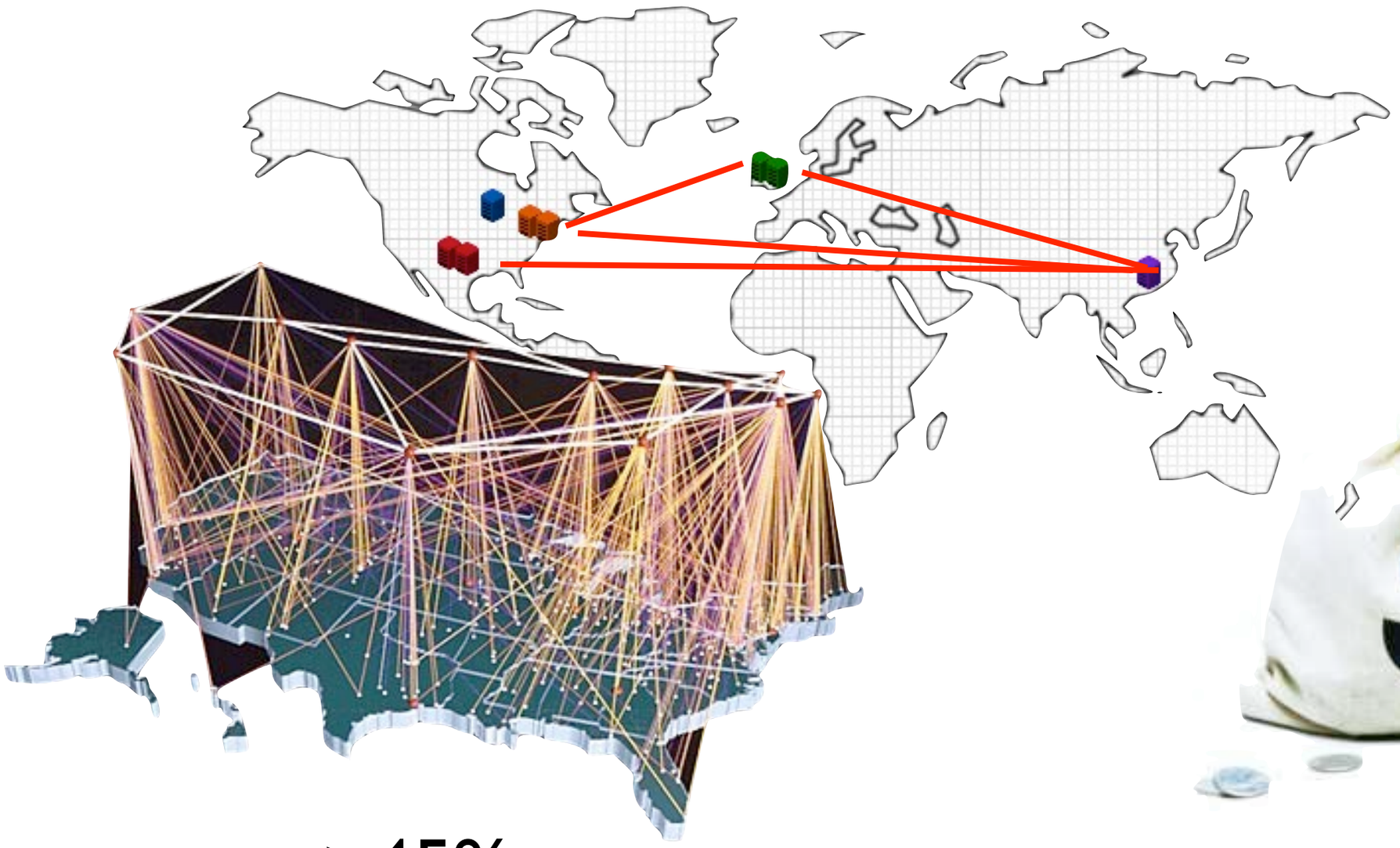
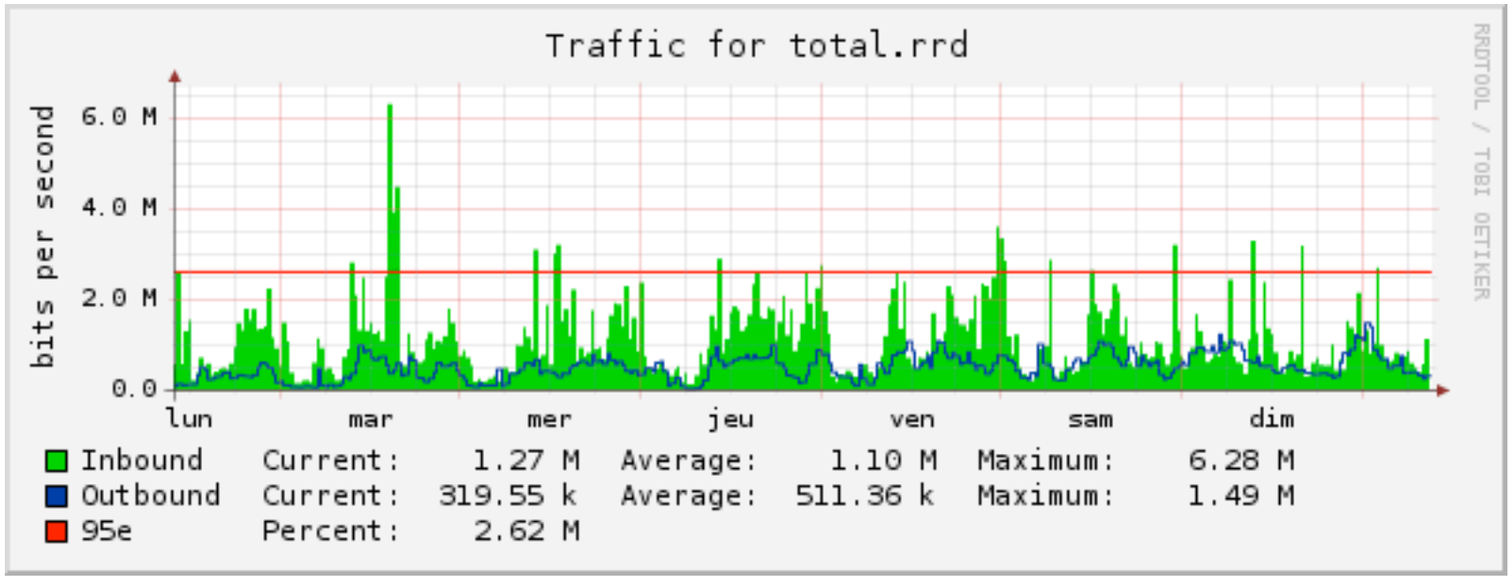


>45%

operational cost

95%



e.g., 5-minute interval, after sorting

$$95\% \times 365 \times 24 \times 60 \times (1/5) = 99864$$

A waste of money

opportunities

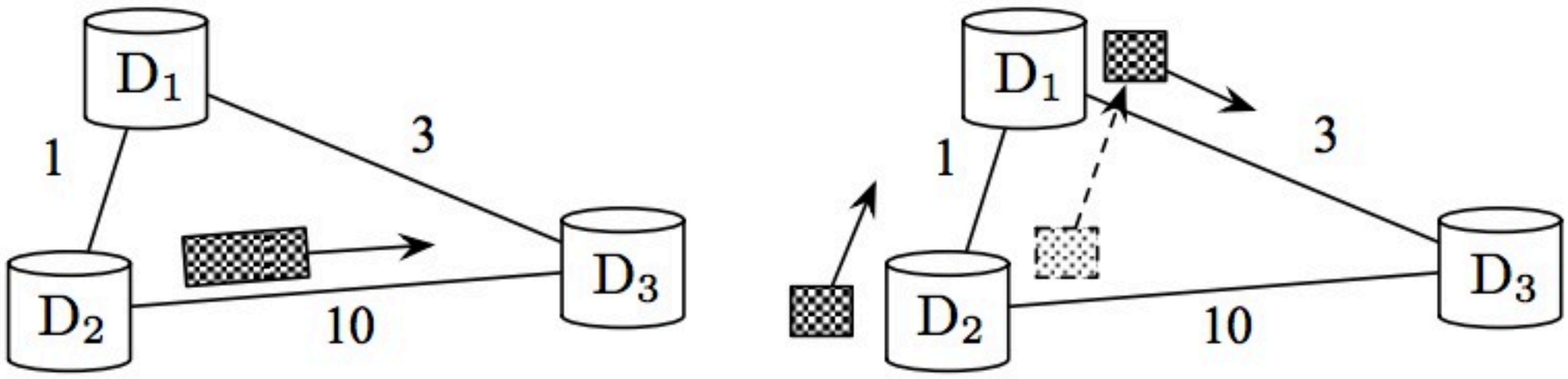
√Prices vary across different overlay links

√delay tolerant

Multi-path + Store&Forward

Multi-path + Store&Forward

$$D2 \rightarrow D3, 6MB, 15min)$$



(a) Without routing and scheduling

(b) With routing and scheduling

$$D_2 \rightarrow D_3$$

$$10 \times 2 = 20$$

$$D_2 \rightarrow D_1 \rightarrow D_3$$

$$1 \times 3 + 3 \times 3 = 12$$

Difficult.

√ How to divide the data block?

√ How to relay?

Flow based solution...

Flow based solution...

eliminate intermediate storage $\frac{6MB}{15min} = 54.6kbps$

√ subset of traffic pairs

√ routing path

minimize operational cost on inter-datacenter traffic, with intermediate nodes being able to help relay data to reduce peak traffic demand.

Postcard: Minimizing Costs on Inter-Datacenter Traffic with Store-and-Forward

$$\mathcal{G} = (\mathcal{V}, \mathcal{E})$$

$k \in \mathcal{K}(t)$ file k

(s_k, d_k, F_k, T_k) <src, dst, file_size, deadline>

I charging period

$\bar{t}$ time interval

$M_{ij}^k(t)$ fraction of k

a_{ij} unit traffic price

$c_{ij}(t)$ link capacity

$$\min_{M_{ij}^k(n)} \quad \sum_{\{i,j\}\in\mathcal{E}} a_{ij} X_{ij}(t) I \tag{1}$$

$$\text{s.t.} \quad \sum_{k\in\mathcal{K}(t)} M_{ij}^k(n) \le c_{ij}(n)\bar{t},\ \forall\{i,j\}\in\mathcal{E} \tag{2}$$

$$\sum_{j\in\mathcal{V}} \sum_{n=t}^{t+\max_k T_k} \left(M_{s_k j}^k(n) - M_{j s_k}^k(n-1)\right) = F_k,$$

$$\sum_{j\in\mathcal{V}} \sum_{n=t}^{t+\max_k T_k} \left(M_{d_k j}^k(n) - M_{j d_k}^k(n-1)\right) = -F_k,$$

$$\sum_{j\in\mathcal{V}} M_{ij}^k(n) - \sum_{j\in\mathcal{V}} M_{ji}^k(n-1) = 0,$$

$$\forall k \in \mathcal{K}(t),\ \forall i \in \mathcal{V}/\{s_k, d_k\} \tag{3}$$

$$M_{ij}^k(n) \ge 0,\ \forall k \in \mathcal{K}(t),\ \forall\{i,j\}\in\mathcal{E} \tag{4}$$

$$T_k' \le T_k,\ \forall k \in \mathcal{K}(t). \tag{5}$$

$$X_{ij}(t) = \max\{X_{ij}(t-1),\ \max_{\max_k T_k} \sum_{k\in\mathcal{K}(t)} M_{ij}^k(n)\}$$

$k \in \mathcal{K}(t)$ → file k

(s_k, d_k, F_k, T_k) →

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Time expanded graph

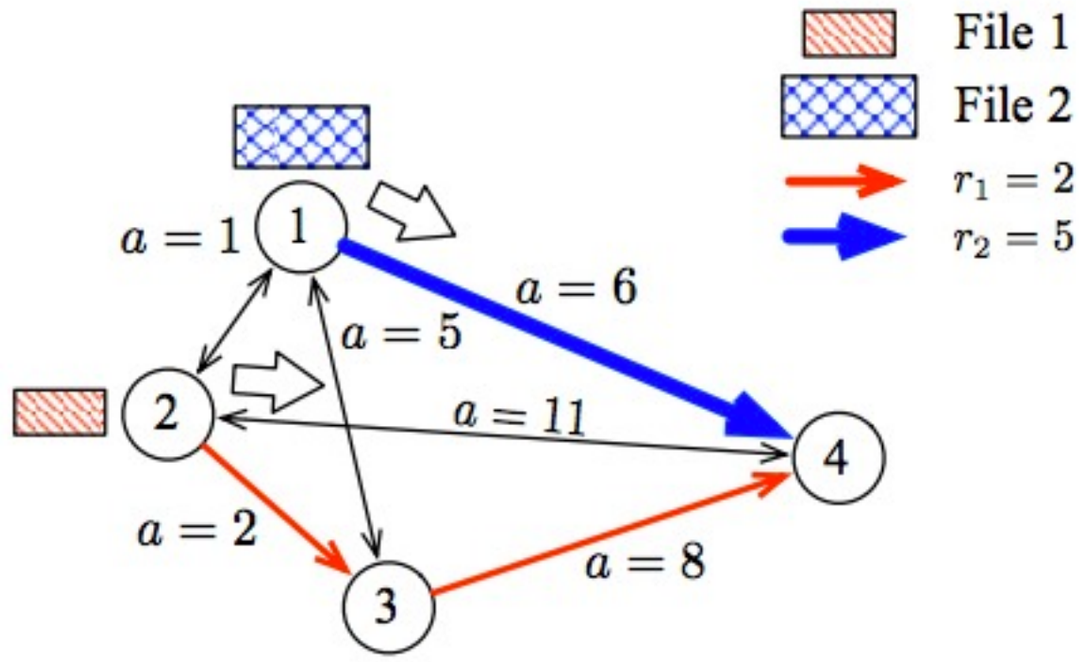
$$\mathcal{G}(t) = (\mathcal{V}(t), \mathcal{E}(t))$$
$$[t, t + \max_k T_k]$$

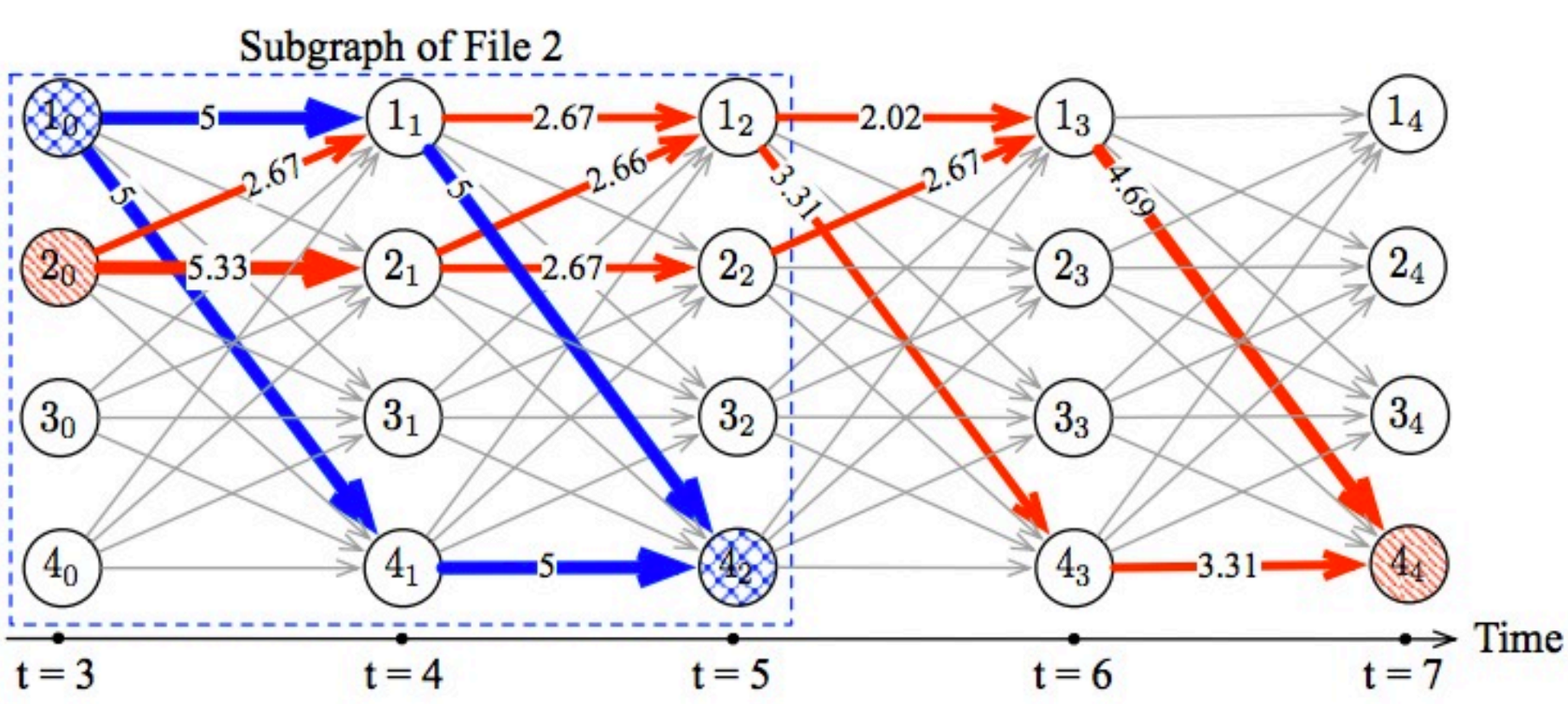
$$\mathcal{G} = (\mathcal{V}, \mathcal{E}) \longrightarrow$$

$$\{i^n | \forall i \in \mathcal{V}, t \leq n \leq t + \max_k T_k\}$$

$$\{i^n j^{n+1} | \forall \{i, j\} \in \mathcal{E}, t \leq n \leq t + \max_k T_k - 1\}$$

$$(s_k^t, d_k^{t+T_k}, F_k)$$


File 1
File 2
$r_1 = 2$
$r_2 = 5$
$a = 1$
$a = 6$
$a = 5$
$a = 11$
$a = 2$
$a = 8$
1
2
3
4


Subgraph of File 2
1_0
2_0
3_0
4_0
1_1
2_1
3_1
4_1
1_2
2_2
3_2
4_2
1_3
2_3
3_3
4_3
1_4
2_4
3_4
4_4
5
2.67
5.33
2.66
2.02
3.31
4.69
3.31
Time
t = 3
t = 4
t = 5
t = 6
t = 7

$$\min_{M_{ij}^k(n)} \quad \sum_{\{i,j\}\in\mathcal{E}} a_{ij} X_{ij}(t) I \tag{1}$$

$$\text{s.t.} \quad \sum_{k\in\mathcal{K}(t)} M_{ij}^k(n) \le c_{ij}(n)\bar{t},\ \forall\{i,j\}\in\mathcal{E} \tag{2}$$

$$\sum_{j\in\mathcal{V}} \sum_{n=t}^{t+\max_k T_k} \left(M_{s_k j}^k(n) - M_{j s_k}^k(n-1)\right) = F_k,$$

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<src, dst, file_size, deadline>

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a_{ij} → unit traffic price

I → charging period

$\bar{t}$ → time interval

$M_{ij}^k(t)$ → fraction of k

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$$X_{ijt} = \max\{X_{ij(t-1)}, \max_{\max_k T_k} \sum_{k \in \mathcal{K}(t)} M_{ijn}^k\}$$

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$$\min_{M_{ijn}^k} \quad \sum_{\{i^n j^{n+1}\} \in \mathcal{E}(t)} a_{i^n j^{n+1}} X_{ijt} I \tag{6}$$

$$\text{s.t.} \quad \sum_{k \in \mathcal{K}(t)} M_{ijn}^k \leq c_{ijn} \bar{t}, \ \forall \{i^n j^{n+1}\} \in \mathcal{E}(t) \tag{7}$$

$$\sum_{j^n \in \mathcal{V}(t)} (M_{s_k j t}^k - M_{j s_k (t-1)}^k) = F_k,$$

$$\sum_{j^n \in \mathcal{V}(t)} (M_{d_k j (t+T_k)}^k - M_{j d_k (t+T_k-1)}^k) = -F_k,$$

$$\sum_{j^n \in \mathcal{V}(t)} M_{ijn}^k - \sum_{j^n \in \mathcal{V}(t)} M_{ji(n-1)}^k = 0,$$

$$\forall k \in \mathcal{K}(t), \forall i^n \in \mathcal{V}(t) \setminus \{s_k^t, d_k^{t+T_k}\} \tag{8}$$

$$M_{ijn}^k \geq 0, \forall k \in \mathcal{K}(t), \forall \{i^n j^{n+1}\} \in \mathcal{E}(t) \tag{9}$$

$$M_{ijn}^k = 0, \forall k \in \mathcal{K}(t), \forall \{i^n j^{n+1} | n > t + T_k\} \tag{10}$$

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→

→ link capacity

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Comments:

√ all files can finish their transmission within charging period

√ dynamic solution is not possible.

√ actual transmission time is hard to derive

√ node explosion time expanded graph

√ no implementation