



Content Fragmentation: A New Inter-Data Center Content Redundancy Scheme to Saving Energy in Optical Cloud Networks

Group Meeting Presentation

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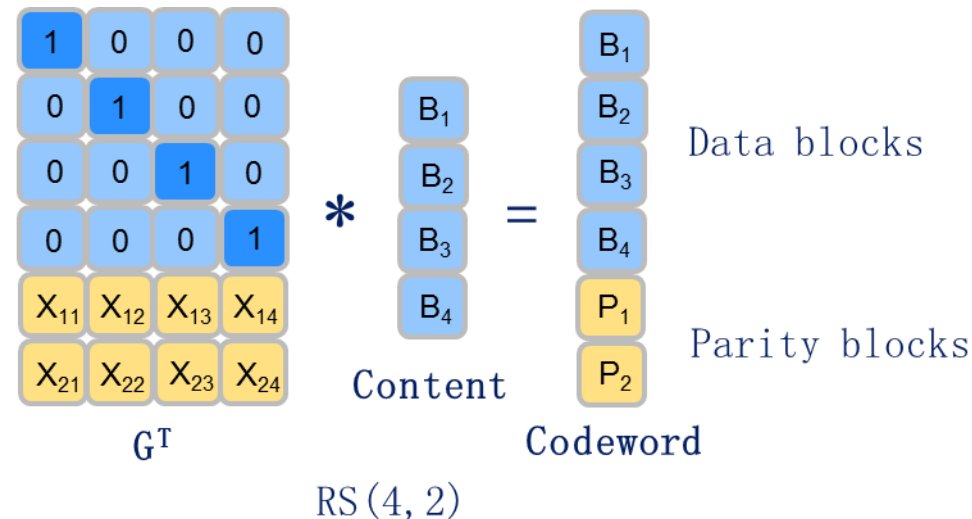
Motivation



- ❑ The rapid growth of content-based cloud services (as video streaming, etc.) is raising concerns on the environmental sustainability of the supporting infrastructure.
- ❑ Traditional inter-DC content redundancy scheme -- Content Replication (CR) failed to save energy on storage, as it usually requires multiple replicas of a content to be distributed across DCs to guarantee resiliency.
- ❑ To explore energy optimization possibilities on storage, in this study, we propose a new scheme called **Content Fragmentation (CF) to achieve less storage redundancy, thus less energy consumption.**
- ❑ However, the tradeoff is that CF consumes more energy than CR on core network and on content decoding.

Content Fragmentation

- ❑ Content is fragmented into k equally-sized data blocks.
- ❑ Erasure code is used to perform content encoding, i.e., encoding k data blocks to r parity blocks of same size.
- ❑ A specific type of erasure code, called Reed-Solomon (RS), is used to provide inter-DC redundancy.
- ❑ RS allows any k blocks out of $(k+r)$ blocks to reconstruct the original content.



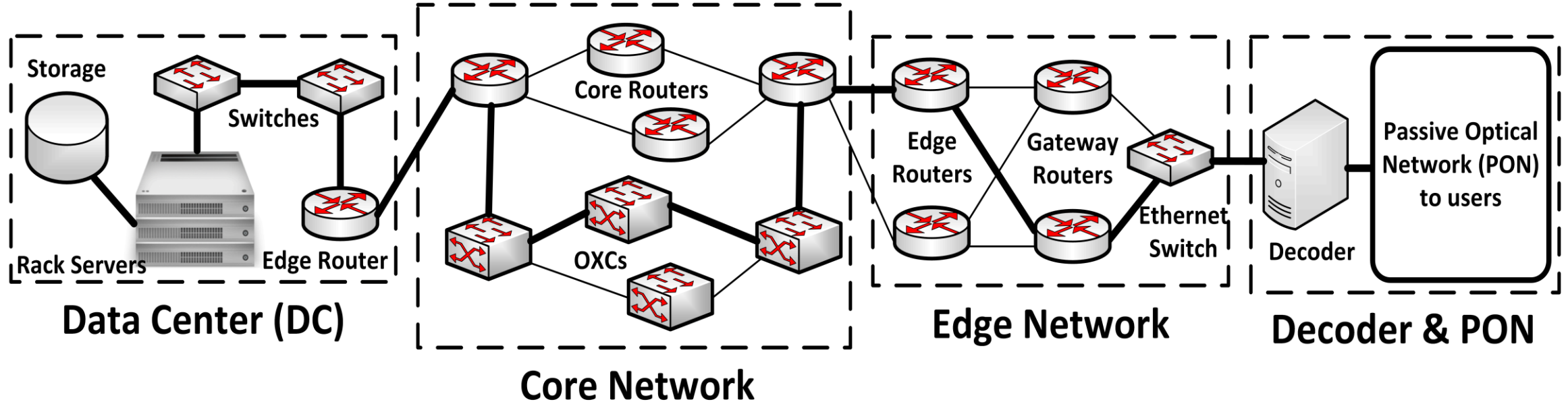
CF Energy Consumption Tradeoff

- ❑ CF consumes less energy on **storage** than CR.
 - ❖ Industry standard CR redundancy level: 3 replicas per content.
 - ✓ 2x more storage usage.
 - ❖ Industry standard CF redundancy level: RS(10, 4).
 - ✓ 0.4x more storage usage.
- ❑ CF could potential consume more energy on **core network** and **content decoding** than CR.
 - ❖ Content retrieving follows reverse-multicast routing.
 - ❖ Content decoding consumes extra energy in CF if there is any data block missing.

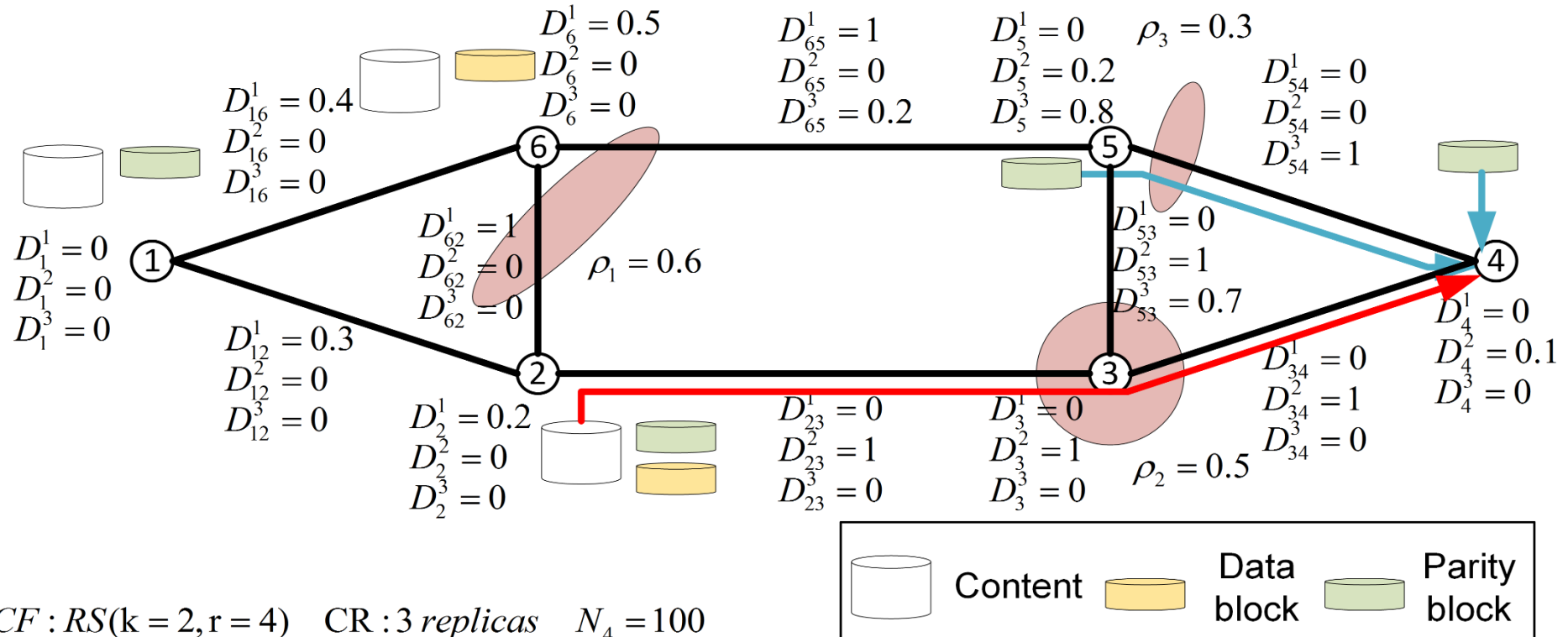
The Goals of This Study

- ❑ We propose and formulate the **content placement and routing assignment problem** with the goal to **minimize energy consumption** while **satisfying QoS constraints such as resiliency and latency** for both CF and CR schemes.
- ❑ This problem is solved optimally by MILP. Due to its complexity, we also propose an efficient meta-heuristic algorithm (M-CPRA).
- ❑ We provide guidelines on how to choose which scheme to use based on three factors: **(1) number of content requests, (2) resiliency, and (3) latency.**

Energy Consumption



QoS Constraint: Disaster Resiliency



$CF : RS(k = 2, r = 4)$ $CR : 3 \text{ replicas}$ $N_4 = 100$

$$R_4 = 1 \cdot 100 \cdot [0.6 \cdot (0 + 0 + 0) + 0.5 \cdot (0.2 + 0 + 0.1) + 0.3 \cdot (0.8 + 1 + 0)] + 1 \cdot 100 \cdot [0.6 \cdot (0) + 0.5 \cdot (0.1) + 0.3 \cdot (0)] = 74$$

$$R'_4 = 2 \cdot 100 \cdot [0.6 \cdot (0.2 + 0 + 0 + 0 + 0) + 0.5 \cdot (0 + 1 + 1 + 1 + 0.1) + 0.3 \cdot (0 + 0 + 0 + 0 + 0)] = 334$$

QoS Constraint: Disaster Resiliency

- Network-wide disaster risk should be upper-bounded.

$$\sum_{s \in S} R_s^{()} \leq R_{th}$$

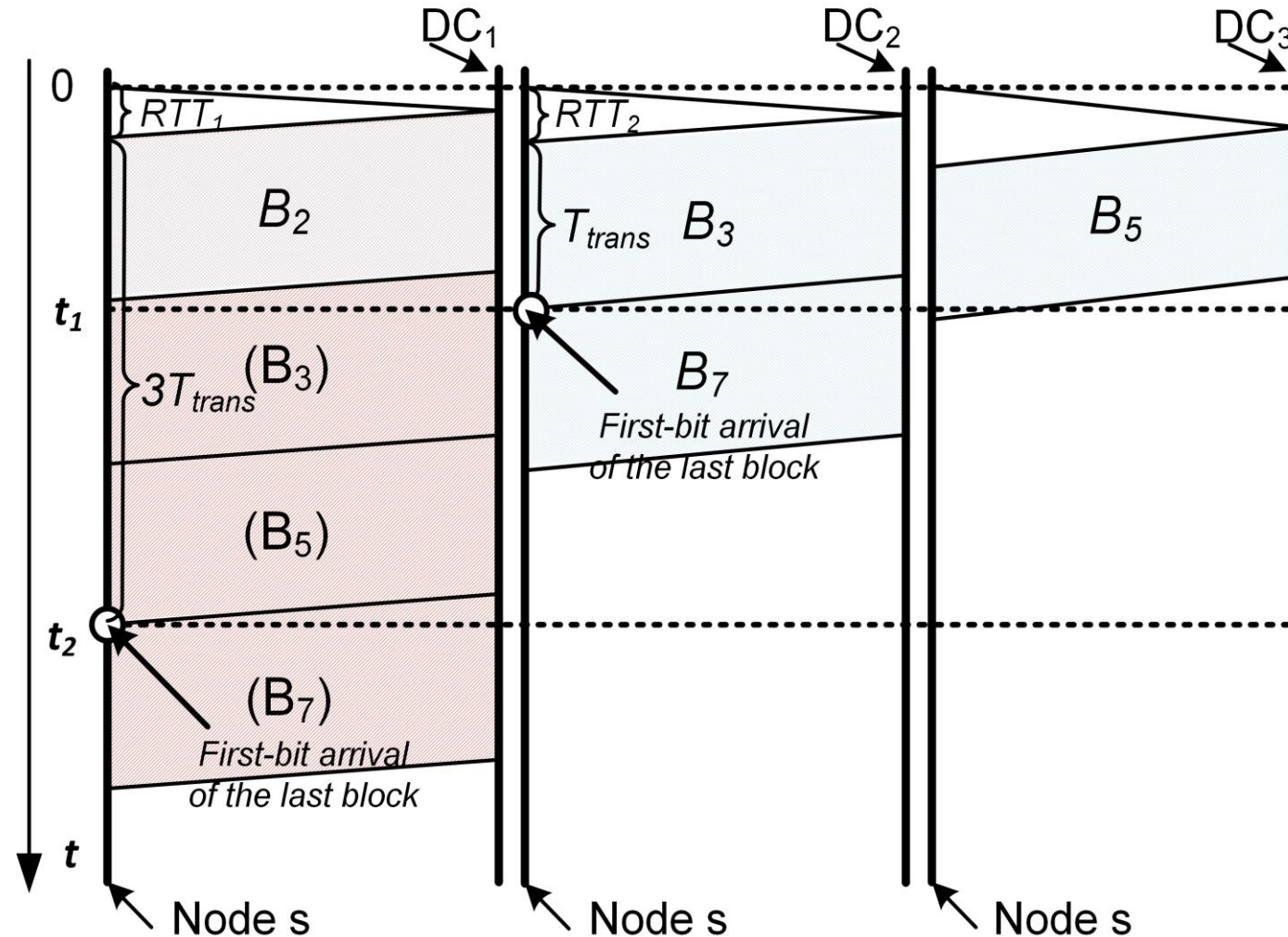
- For a single location, the number of content blocks/replicas to be placed should also be upper-bounded.

$$\sum_{i \in I^{()}} C_{id} \leq r (|I'| - 1) \quad \forall d \in DS$$

QoS Constraint: Latency

- ❑ Latency is defined as the amount of time elapsed from the moment user sends out a content request until the content arrives.
- ❑ We assume that networks and DCs are lightly loaded so that processing delay and queueing delay are kept under budget and not modeled. We focus on content propagation delay and transmission delay for both CF and CR schemes.
- ❑ For CR, latency can be approximated as round-trip propagation delay from user to its serving content replica.
- ❑ For CF, there are two scenarios:
 - ❖ First data block (B_1) is retrieved:
 - ✓ Latency can be approximated as the round-trip propagation delay from user to B_1 -hosting DC.
 - ❖ First data block is not retrieved:
 - ✓ Latency can be approximated as the time when request is sent out till the first bit of the final block arrives.

QoS Constraint: Latency

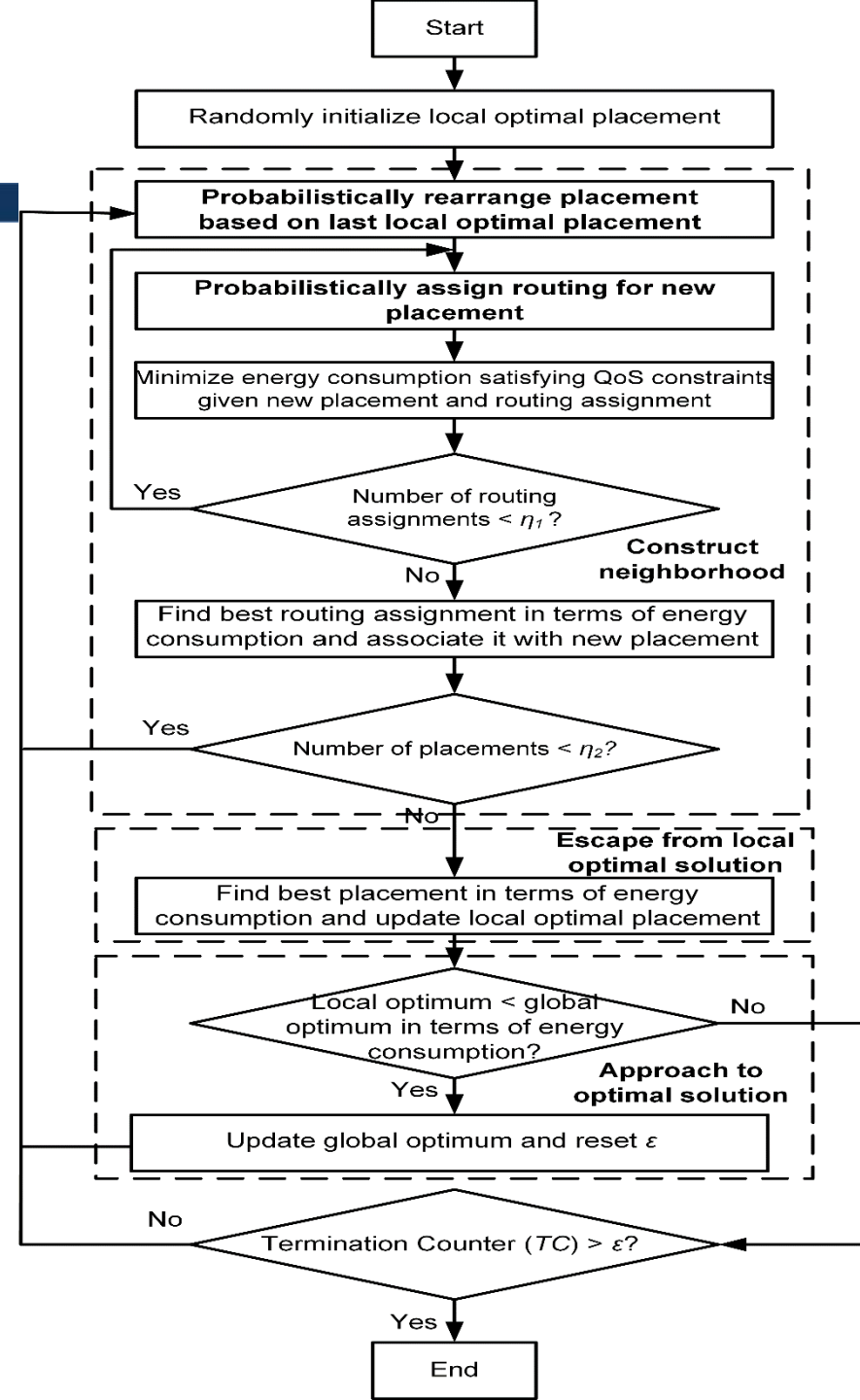


QoS Constraint: Latency

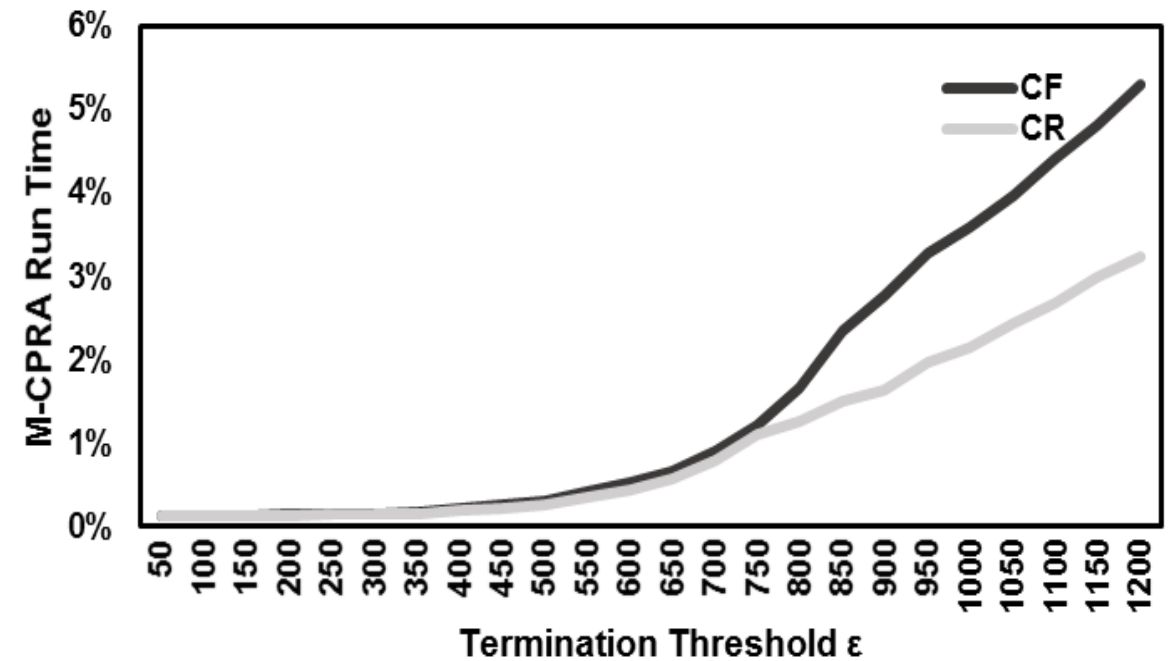
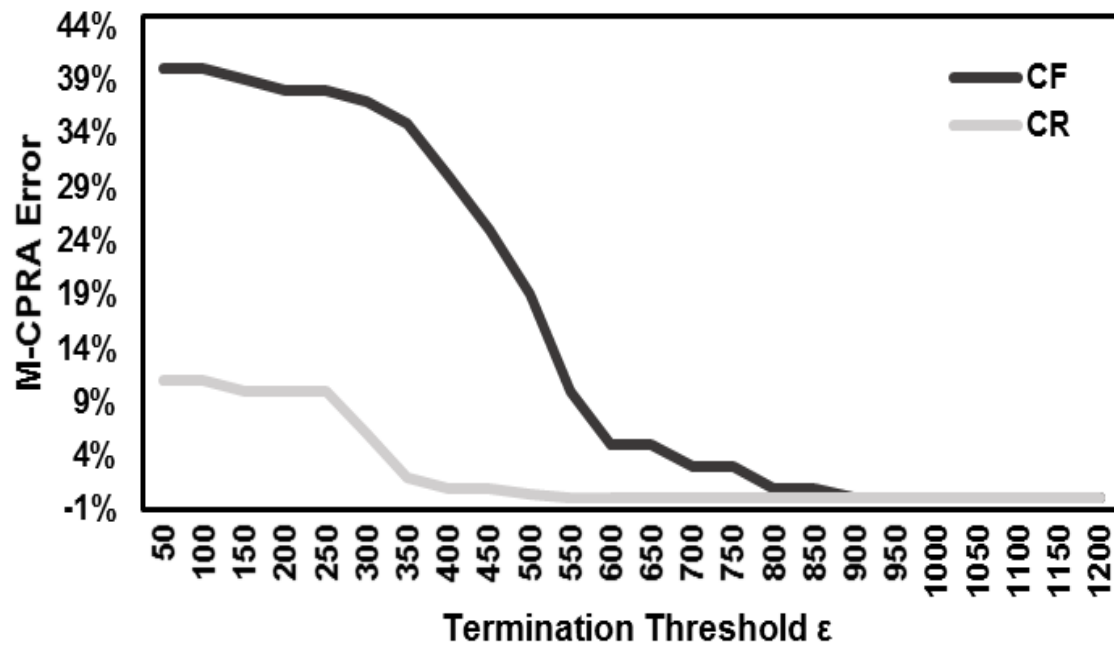
- Latency of each source node should be upper-bounded.

$$L_s^{(\text{yes/no})} \leq L_{th} \quad \forall s \in S$$

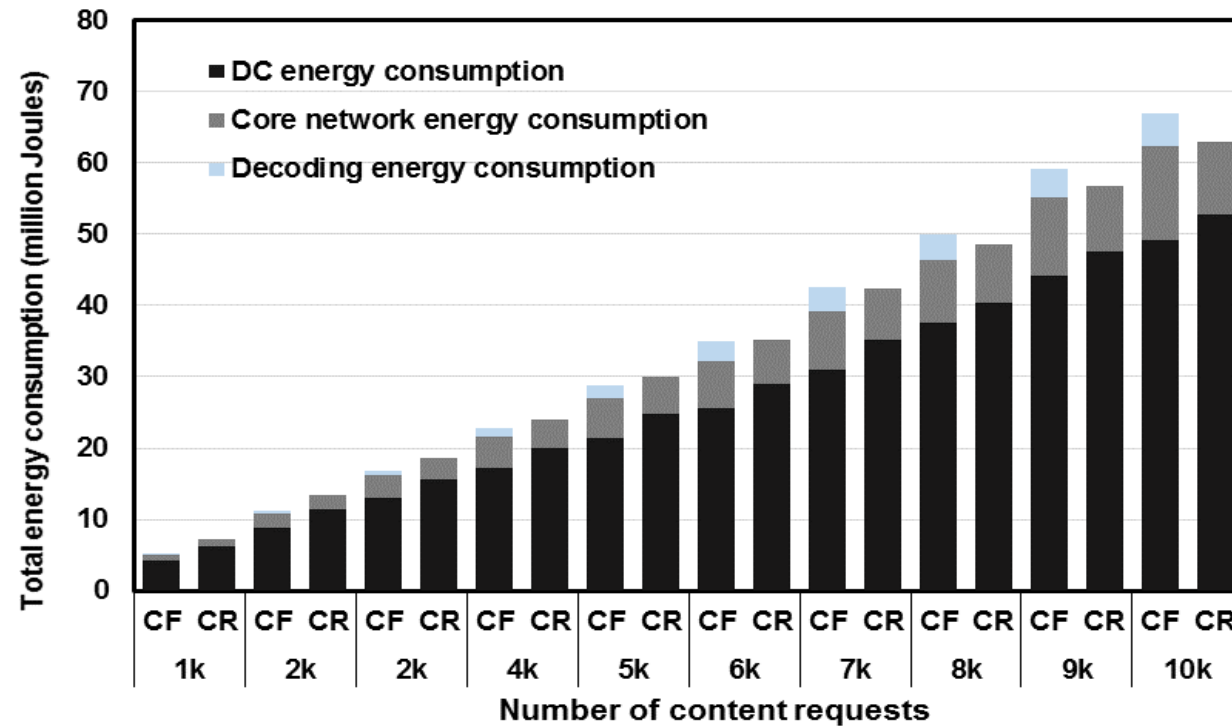
M-CPRA Algorithm



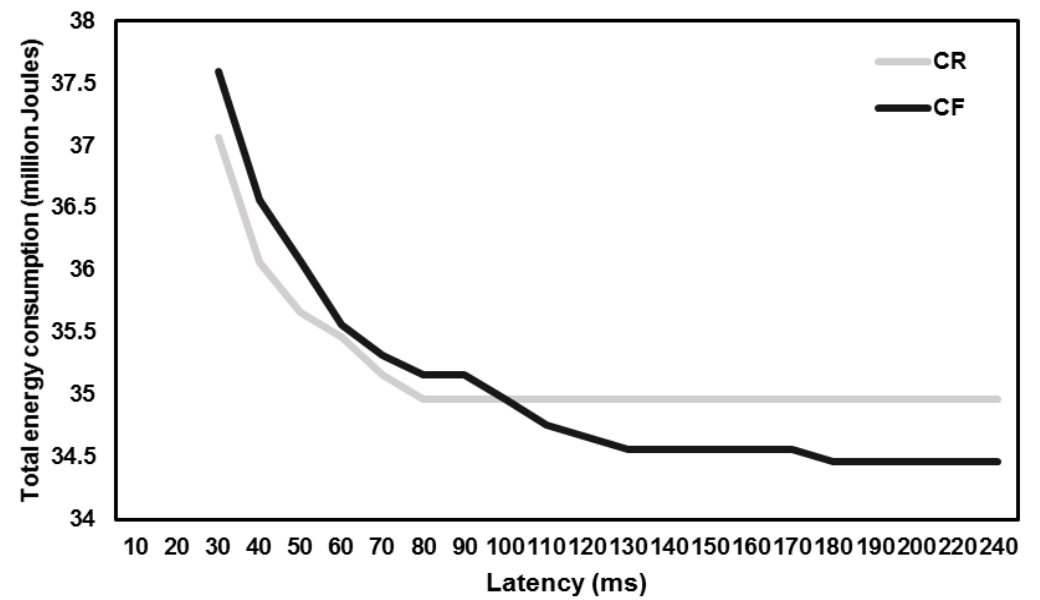
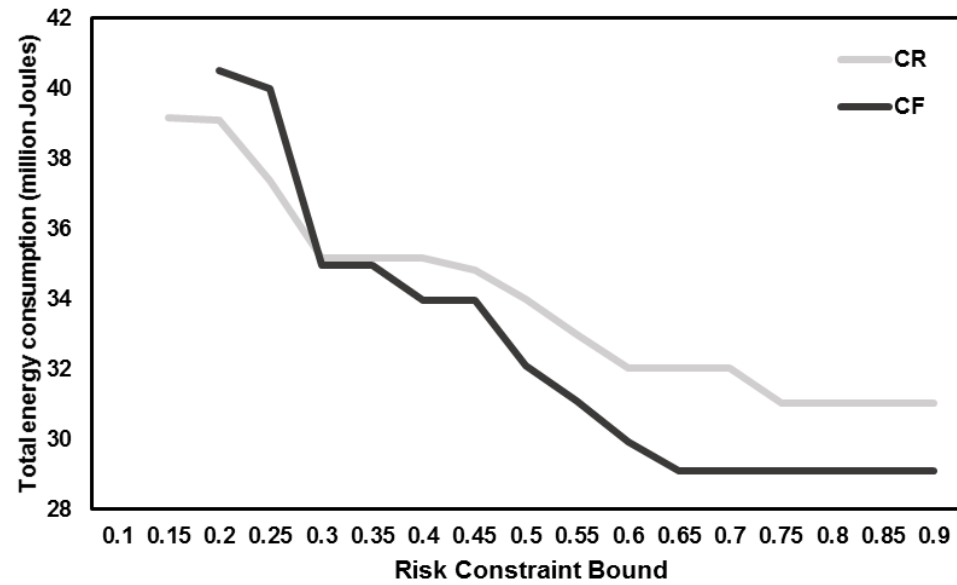
M-CPRA VS MILP



CF or CR



CF or CR





Thank you!