Collaborative Message Distribution via Device-to-Device Communications

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ABSTRACT

Device-to-device (D2D) communications can provide many promising applications such as message dissemination and content distribution. With D2D communications, certain devices can serve as the content providers to fulfill the content requests of other devices. This study introduces an important problem for D2D-assisted content distribution. Aiming to different goals, this problem can be formulated from different perspectives as a multiple-choice knapsack problem (MCKP), a weighted set cover problem (WSCP), and a Lagrangian relaxation problem (LRP). Here, we evaluate three approaches for these problems, including a fully polynomial-time approximation scheme (FPTAS), a greedy algorithm, and a heuristic algorithm based on Lagrangian relaxation. Simulations are conducted to compare the performance in the static and dynamic scenarios in terms of total cost, unit cost, D2D offload ratio, and service latency.

SYSTEM MODEL

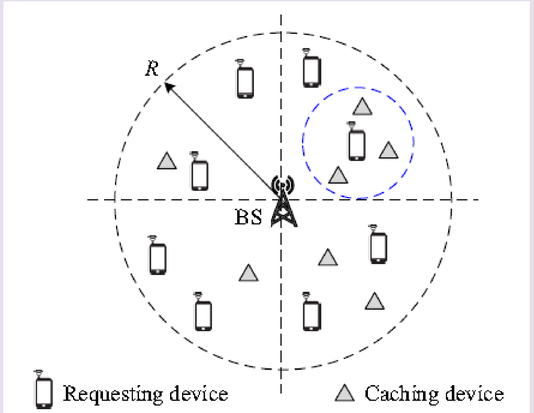

Fig. 1. Content distribution scenario.

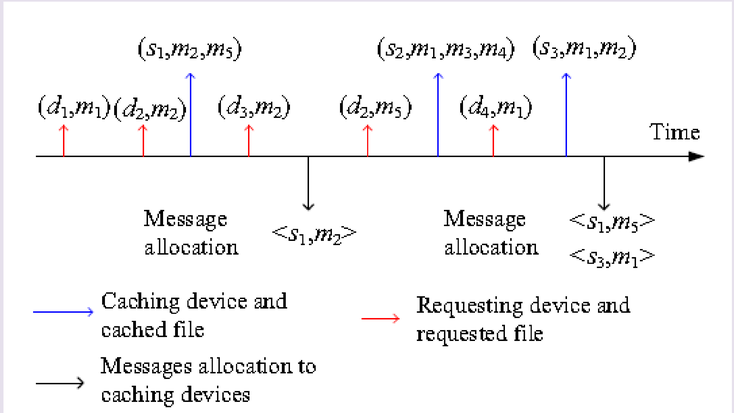

Fig. 2. Content distribution scenario.

SIMULATION RESULTS

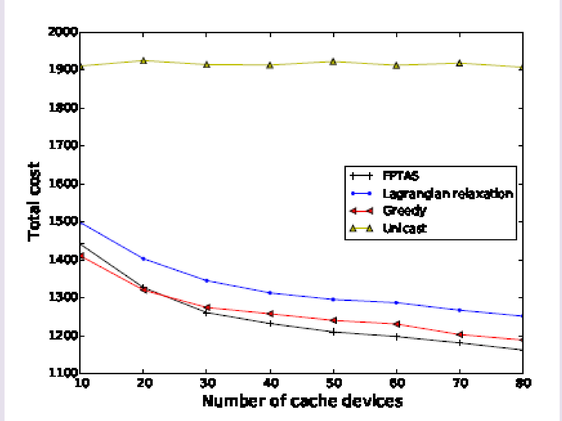

Fig. 3. Total cost of static scenario.

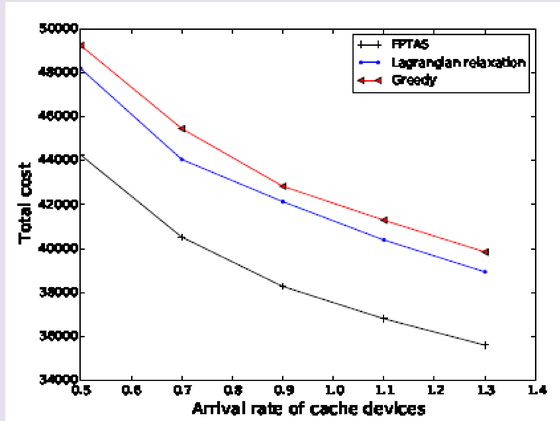

Fig. 4. Total cost of dynamic scenario.

MCKP FORMULATION

$$\text{maximize} \quad \sum_{i=1}^{n} \sum_{m_k \in M_i'} (c_{Bk_i} - c_{ik}) x_{ik}$$

$$\text{subject to} \quad \sum_{i=1}^{n} \sum_{m_k \in M_i'} c_{ik} x_{ik} \leq C$$

$$\sum_{m_k \in M_i'} x_{ik} = 1, \forall \boldsymbol{s}_i \in S$$

$$x_{ik} \in \{0,1\}, \forall \boldsymbol{s}_i \in S, m_k \in M_i'.$$

WSCP FORMULATION

$$\text{minimize} \quad \sum_{i=1}^{n'} \sum_{m_k \in M_i} c_{ik} x_{ik}$$

$$\sum_{i=1}^{n'} x_{ik} t_{ij} \geq 1,$$

$$\forall r_{jk} = 1, m_k \in M_i, d_j \in D$$

$$x_{ik} \in \{0,1\}, \forall \boldsymbol{s}_i \in S \cup S_{BS}, \forall m_k \in M_i$$

LRP FORMULATION

$$\text{minimize} \quad \sum_{i=1}^{n'} \sum_{m_k \in M_i} c_{ik} x_{ik}$$

$$\text{subject to} \quad \sum_{m_k \in M_i} x_{ik} \leq 1, \forall \boldsymbol{s}_i \in S \cup S_{BS}$$

$$\sum_{i=1}^{n'} x_{ik} t_{ij} \geq 1,$$

$$\forall r_{jk} = 1, m_k \in M_i, d_j \in D$$

$$x_{ik} \in \{0,1\}, \forall \boldsymbol{s}_i \in S \cup S_{BS}, \forall m_k \in M_i$$

CONCLUSION & FUTURE WORK

The simulation results show that MKCP solution outperforms the other two in terms of total cost. This is because the MKCP solution can find better message allocation that diverts more requests to be successfully fulfilled by D2D multicast. In the future, we may explore better approximation algorithms for the hypergraph matching problem to improve the heuristic algorithm based on Lagrangian relaxation.