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Heuristics for static cloudlet location

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Abstract

Major interest is currently given to the integration of clusters of virtualization servers, also referred to as 'cloudlets', into the access network to allow higher performance and reliability in the access to mobile edge computing services. We tackle the facility location problem arising in the planning of these networks. Due to the complexity of the network topology, and the number of operational constraints, methods from the literature are hard to adapt. While in [1] we discussed the application issues, considering a real test case, in this paper we focus on the algorithmic ones, providing matheuristics solution algorithms for the static case, and an experimental insight on their computational behavior.

Keywords: telecommunications, facility location, matheuristics

Model. Let B be a set of access point (AP) locations. Let I, J and K be a set of sites where aggregation, core nodes and cloudlet facilities can be installed, resp.. Our static cloudlet location problem asks to design a two-level AP-aggregation-core network, to locate cloudlets on it, and to assign APs to cloudlets, minimizing installation costs, respecting cloudlet capacities and service level agreements on maximum delay and available bandwidth on paths between APs and cloudlets. We assume a superposition of stars topology: any AP is connected to a single aggregation node, and each aggregation node to a single core node, while a full mesh is built among cores. For each AP $s \in B$, let δ_s^u be the number of users connecting to s and δ_s^b their overall

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bandwidth consumption. Let l_i, m_j, c_k be the fixed cost for activating an aggregation node in $i \in I$, a core node in $j \in J$ and a cloudlet facility in $k \in K$, resp.. Let C denote the number of users that each cloudlet can serve. Let $d_{i,j}$ and $u_{i,j}$ be the length and bandwidth capacity of each link $(i,j) \in E = (B \times I) \cup (I \times J) \cup (J \times J)$. We assume low latency to be enforced by imposing both a maximum sum of links' length ($\bar{D}$) and number of hops ($\bar{H}$) in a path from AP to its cloudlet, and a maximum distance ($\bar{d}$) between connected nodes. We define as S^{sk} the set of paths from APs to cloudlets such that $\sum_{(i,j)\in p} d_{(i,j)} \leq \bar{D}$, $|p| \leq \bar{H}$ and $d_{(i,j)} \leq \bar{d}$ for all $(i,j) \in p\}$, with $|p|$ denoting the number of links forming path p. We introduce three sets of variables. The first corresponds to binary location variables: x_i, y_j and z_k take value 1 if sites $i \in I$, $j \in J$ and $k \in K$, resp., are selected to host facilities. The second corresponds to binary routing variables: $r_p^{s,k}$ take value 1 if users in AP $s \in B$ are served by a cloudlet in $k \in K$, and the corresponding traffic is routed along path $p \in \bar{S}^{sk}$. The third corresponds to network topology binary variables: $t_{s,i}$, $w_{i,j}$ and $o_{m,n}$ take value 1 if a link is established between an AP s and an aggregation node i, an aggregation node i and a core node j, two core nodes m and n, resp.. Moreover, let $U \in [0,1]$, represent the maximum allowed link utilization ratio. We formulate our problem as follows.

$$\min \sum_{i\in I} l_i x_i + \sum_{j\in J} m_j y_j + \sum_{k\in K} c_k z_k \tag{1}$$

$$\text{s.t.} \sum_{p\in S^{sk}|i\in p} r_p^{s,k} \leq x_i \ , \ \forall s \in B, \forall k \in K, \forall i \in I \tag{2}$$

$$\sum_{p\in S^{sk}|j\in p} r_p^{s,k} \leq y_j \ , \ \forall s \in B, \forall k \in K, \forall j \in J \tag{3}$$

$$\sum_{p\in S^{sk}} r_p^{s,k} \leq z_k \ , \ \forall s \in B, \forall k \in K \tag{4}$$

$$\sum_{k\in K} \sum_{p\in S^{s,k}} r_p^{s,k} = 1 \ , \ \forall s \in B \tag{5}$$

$$\sum_{s\in B} \sum_{p\in S^{s,k}} \delta_s^u r_p^{s,k} \leq C z_k \ , \ \forall k \in K \tag{6}$$

$$\sum_{s\in B} \sum_{k\in K} \sum_{\substack{p\in S^{s,k} \\ |(i,j)\in p}} \delta_s^b r_p^{s,k} \leq u_{(i,j)} U(w_{i,j} + o_{i,j} + t_{i,j}) \ , \ \forall (i,j) \in E \tag{7}$$

We minimize installation costs (1); (2)-(4) impose that no path can be selected unless devices are installed on its sites; (5)-(7) ensure that each AP is assigned