Green Latency-aware Data Deployment in Data Centers: Balancing Latency, Energy in Networks and Servers

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Model

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Motivation

• Two concerns exist in service provisioning by data centers
  – Users require to experience low latency while accessing data from the data centers
  – Reduce the power consumed by network transport and servers in the data centers
Problem

• We tackle the problem of green data deployment in the data centers, taking into account the three factors of latency, energy consumption of the data centers and the network transport.

• The cost of deploying data on a server in a data center integrates the three factors above.
  – each factor has a coefficient in the cost function.
Objective Function

Minimize:
\[
\lambda_1 \sum_{u_i,dc_j,s_m,d_k} \text{rep}(dc_j, s_m, d_k)p(u_i | d_k)l(u_i, dc_j)
+ \lambda_2 \sum_{dc_j,s_m} \text{rep}(dc_j, s_m)e_S(d_{c_j}, s_{m})
+ \lambda_3 \sum_{u_i,dc_j,s_m,d_k} s(d_k)\text{rep}(dc_j, s_m, d_k)p(u_i | d_k)e_I(u_i, dc_j)
\]

Subject to:
\[
\text{rep}(dc_j, s_m) = \sum_{d_k} \text{rep}(dc_j, s_m, d_k)
\]
\[
\sum_{dc_j,s_m} \text{rep}(dc_j, s_m, d_k) = 1
\]
\[
e_S(d_{c_j}, s_{m}) = P_{s_m}^{dc_j} * PUE(d_{c_j})
\]
\[
\sum_{d_k} \text{rep}(dc_j, s_m, d_k)s(d_k) \leq C(s_m, dc_j), \forall s_m, dc_j
\]
• $\lambda_1$, $\lambda_2$, and $\lambda_3$ are the weights of the sub-objectives of the latency, the energy consumption of the data centers and the network transport, respectively.

• $\text{rep}(dc_j, s_m, d_k)$ indicates whether data $d_k$ is deployed in server $s_m$ in data center $dc_j$.

• $p(u_i | d_k)$ is the probability that a given request is asking for data $d_k$ and it comes from user group $u_i$.

• $l(u_i, dc_j)$ is the latency between user group $u_i$ and data center $dc_j$.

• $\text{rep}(dc_j, s_m)$ is the indicator whether server $s_m$ in data center $dc_j$ has been deployed some data.
• $e_{S(d_{c_j}, s_m)}$ is the energy consumption of server $s_m$ in data center $d_{c_j}$.

• $s(d_k)$ is the size of data $d_k$.

• $e_I(u_i, d_{c_j})$ is the energy required to transport one bit from data center $d_{c_j}$ to user group $u_i$ through the Internet.

• $\text{PUE}(d_{c_j})$ is the PUE of data center $d_{c_j}$ is the power of server $s_m$ in data center $d_{c_j}$.

• $C(s_m, d_{c_j})$ is the capacity of server $s_m$ in data center $D_{c_j}$. 
GLDD (Green Latency-aware Data Deployment)

• When processing each data chunk $d_k$, GLDD searches the servers in all the data centers with the least cost to deploy data $d_k$.

• Each server in each data center is checked to obtain the cost to accommodate data $d_k$ on the server if the server has enough capacity.

• The cost of deploying data $d_k$ on server $s_m$ in data center $dc_j$ integrates the three factors of the latency, the power consumed by the servers and the network transport.
Algorithm 1 GLDD Algorithm

Input: Data Request Probability Matrix $P(u_i \mid d_k)$
Input: Network Latency Cost Matrix $L(u_i, d_{c_j})$
Input: Network Transport Energy Cost Matrix $E_I(u_i, d_{c_j})$
Input: Servers Power Cost Matrix $E_S(u_i, d_{c_j})$
Input: Data Size Queue $S(d_k)$
Output: $Rep(d_{c_j}, s_m, d_k)$

Sort $S(d_k)$ by non-ascending order of data size.

while Queue of $S(d_k)$ not empty do
    get the head $d_k$ from the Queue $S(d_k)$
    for each data center $d_{c_j}$ do
        for each server $s_m$ in data center $d_{c_j}$ do
            if server $s_m$ has enough capacity to accommodate data $d_k$ then
                Calculate the cost to deploy data $d_k$ on server $s_m$ in data center $d_{c_j}$;
            end if
        end for
    end for
    Obtain the server $s_m$ in the data center $d_{c_j}$ that costs the least and has enough capacity to accommodate the data $d_k$.
    $C(s_m, d_{c_j})=C(s_m, d_{c_j}) - S(d_k)$
    $rep(d_{c_j}, s_m, d_k)=true$
end while
Return $Rep(d_{c_j}, s_m, d_k)$
We evaluate the performance of the algorithm GLDD by comparing GLDD with the algorithm FORTE proposed in SIGCOMM'12.