Joint Radio and Computational Resource Allocation in IoT Fog Computing

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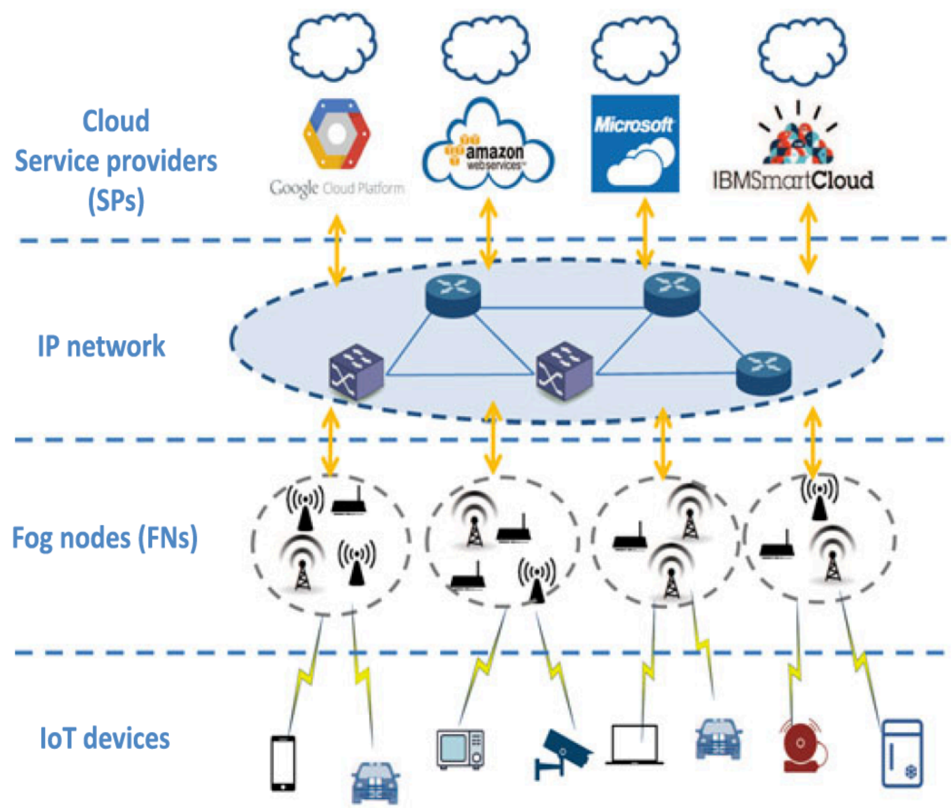
Radio and Computational Resrouce Allocation Problem in IoT Fog Computing

- Goal: optimize the system performance and improve user satisfaction
- Factors: service delay, link quality, mandatory benefit
- Problem: maps user and resource pair



User Satisfaction

- Service delay is used as satisfaction measurement
- Transmit rate = $r_{k,l}^{i,j} = w_k^j \log\left(1 + \Gamma_{k,l}^{i,j}\right)$
- Service delay = $t_{k,l}^{i,j} = t_{\text{trans}} + t_{\text{proc}} + t_{\text{recv}} = \frac{D_i}{r_{k,l}^{i,j}} + \frac{DC_i}{c_{k,l}^{i,j}} + \delta t.$

SP Revenue

- Price offer is used as SP revenue measurement
- Offer from each user:

$$O_i = f(D_i, T_i) = a\frac{D_i}{T_i}$$

- Total revenue for each SP:

$$Rev_j = \sum_{u_i \in \mathcal{U}} \rho_{k,l}^{i,j} O_i .$$

Problem Formulation

$$\max_{\rho_{k,l}^{i,j}} : \quad \frac{\sum_{u_i \in \mathcal{U}} CP(i)}{M} \tag{9}$$

Overall cost performance for users

$$\text{s.t.} \quad : \quad \rho_{k,l}^{i,j} t_{k,l}^{i,j} \leq T_i,$$
$$\forall u_i \in \mathcal{U}, rp_{l,k}^j \in \mathcal{RP}^j, sp_j \in \mathcal{SP}, \tag{10}$$

Delay requirement

$$\rho_{k,l}^{i,j} \Gamma_{k,l}^{i,j} \geq \Gamma_{min},$$
$$\forall u_i \in \mathcal{U}, rp_{l,k}^j \in \mathcal{RP}^j, sp_j \in \mathcal{SP}, \tag{11}$$

SINR requirement

$$\sum_{u_i \in \mathcal{U}, fn_l^j \in \mathcal{FN}^j} \rho_{k,l}^{i,j} \leq q_R, \forall w_k^j \in \mathcal{W}^j, sp_j \in \mathcal{SP}, \tag{12}$$

Capacity constraint for channel

$$\sum_{u_i \in \mathcal{U}, w_k^j \in \mathcal{W}^j} \rho_{k,l}^{i,j} \leq q_C, \forall fn_l^j \in \mathcal{FN}^j, sp_j \in \mathcal{SP}, \tag{13}$$

Capacity constraint for fog node

$$\sum_{u_i \in \mathcal{U}, rp_{l,k}^j \in \mathcal{RP}^j} \rho_{k,l}^{i,j} \leq q_{SP}, \forall sp_j \in \mathcal{SP}, \tag{14}$$

Capacity constraint for SP

$$\rho_{k,l}^{i,j} \in \{0, 1\}, \tag{15}$$

SPA Algorithm

Algorithm 1: SPA-(S,P) Algorithm.

Input: $\mathcal{U}, \mathcal{SP}, \mathcal{W}, \mathcal{FN}, \mathcal{PL}^{user}, \mathcal{PL}^{SP}$;
Output: Matching $\mathcal{M}$;
Initialization: set $\mathcal{M}$ empty, set all users free;

while some user u_i is free and u_i has a non-empty preference list **do**
 for all $u_i \in \mathcal{U}$ **do**
  u_i proposes to the first entity $rp^j_{l,k}$ in $\mathcal{PL}^{user}_i$, and then remove $rp^j_{l,k}$ from $\mathcal{PL}^{user}_i$;
  $\mathcal{M} \leftarrow \mathcal{M} \cup (u_i, rp^j_{l,k})$;
 end for
 for all $rp^j_{l,k}, rp^j_{l,k} \in \mathcal{RP}^j, sp_j \in \mathcal{SP}$ **do**
  while $rp^j_{l,k}$ is over-subscribed **do**
   Find the worst pair $(u_{\text{wst}}, rp_{\text{wst}})$ assigned to $rp^j_{l,k}$ in sp_j's list;
   $\mathcal{M} \leftarrow \mathcal{M} / (u_{\text{wst}}, rp_{\text{wst}})$;
  end while
 end for
 for all $sp_j \in \mathcal{SP}$ **do**
  while sp_j is over-subscribed **do**
   Find the worst pair $(u_{\text{wst}}, rp_{\text{wst}})$ in sp_j's list;
   $\mathcal{M} \leftarrow \mathcal{M} / (u_{\text{wst}}, rp_{\text{wst}})$;
  end while
 end for
end while
Terminate with a matching $\mathcal{M}$.

User-Oriented Cooperation Strategy

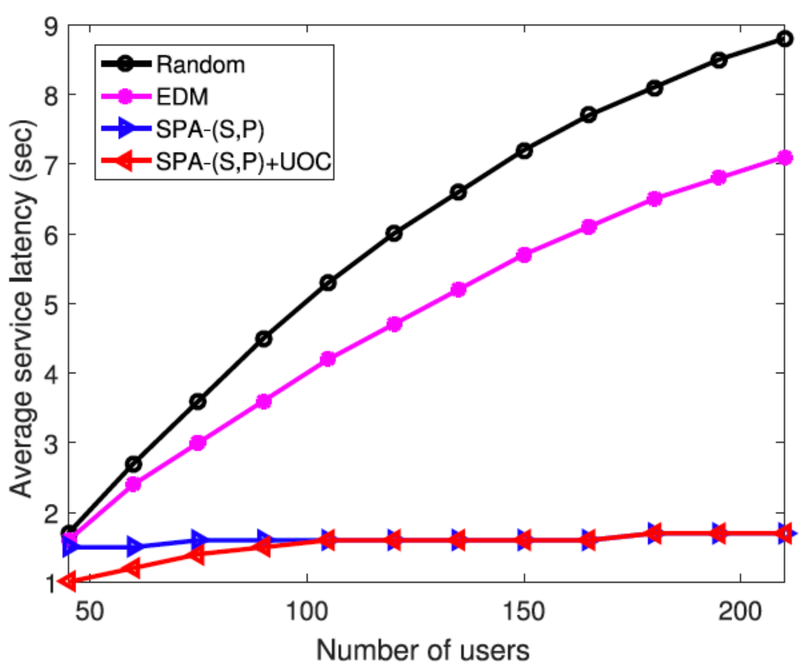
Algorithm 2: User-Oriented Cooperation (UOC) Strategy.

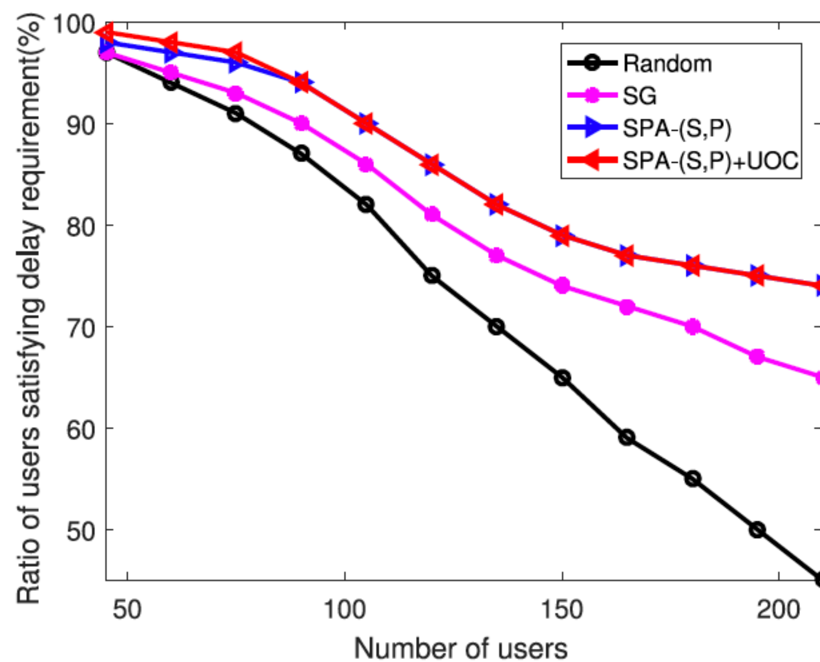
Input: Existing matching $\mathcal{M}_0$;
Output: Pareto optimal matching $\mathcal{M}_s$.

$\mathcal{M}_t = \mathcal{M}_0$;
while $\mathcal{M}_t$ is "unstable" (user, user) pairs $\mathcal{BP}$ **do**
  for all $(u_{i1}, u_{i2}) \in \mathcal{BP}$ **do**
    if $\exists u \in \mathcal{M}_t(rp_{i1}) \cup \mathcal{M}_t(rp_{i2})$, $\Delta U(u) < 0$ **then**
      (u_{i1}, u_{i2}) are not allowed to switch partners;
    else
      (u_{i1}, u_{i2}) are allowed to switch partners;
    end if
  end for
  Find the optimal BP $(u_{i1}^*, u_{i2}^*) \in \mathcal{BP}$;
  u_{i1}^* and u_{i2}^* switch partners;
  $\mathcal{M}_{t+1} \leftarrow \mathcal{M}_t / \{(u_{i1}^*, \mathcal{M}_t(u_{i1}^*)), (u_{i2}^*, \mathcal{M}_t(u_{i2}^*))\}$;
  $\mathcal{M}_{t+1} \leftarrow \mathcal{M}_t \cup \{(u_{i1}^*, \mathcal{M}_t(u_{i2}^*)), (u_{i2}^*, \mathcal{M}_t(u_{i1}^*))\}$;
  Update $\mathcal{PL}^{user}$ based on $\mathcal{M}_t$;
end while
$\mathcal{M}_s = \mathcal{M}_t$.

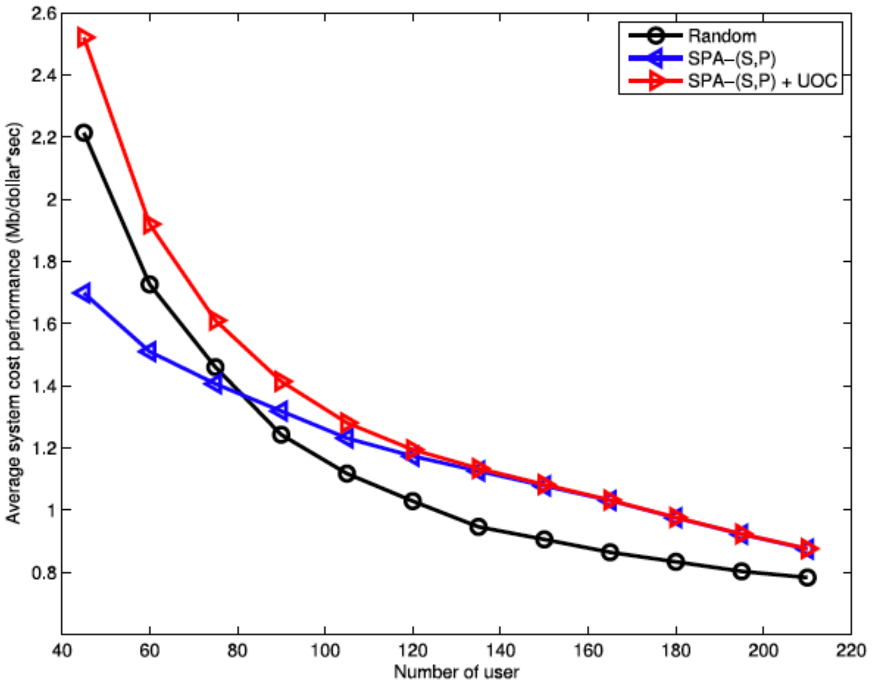
Performance Evaluation

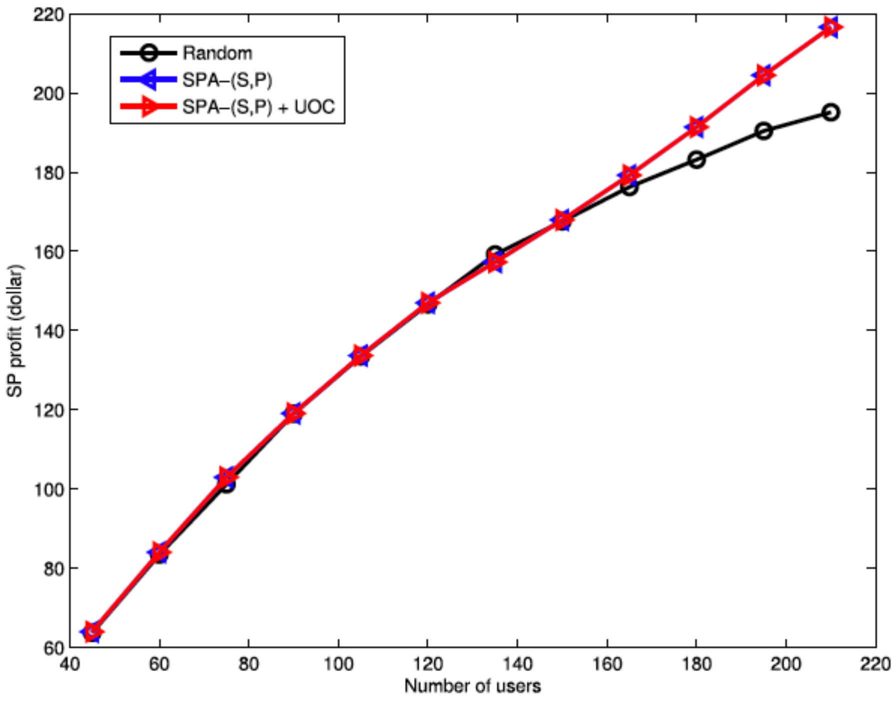
- Setup:
  - Each SP owns 5 channel with bandwidth 5MHz
  - Each fog node computation ability $[5,6] * 10^{10}$ $cycles/sec$
  - Data size and delay requirement of each user [2,8]Mb, [6,7]sec



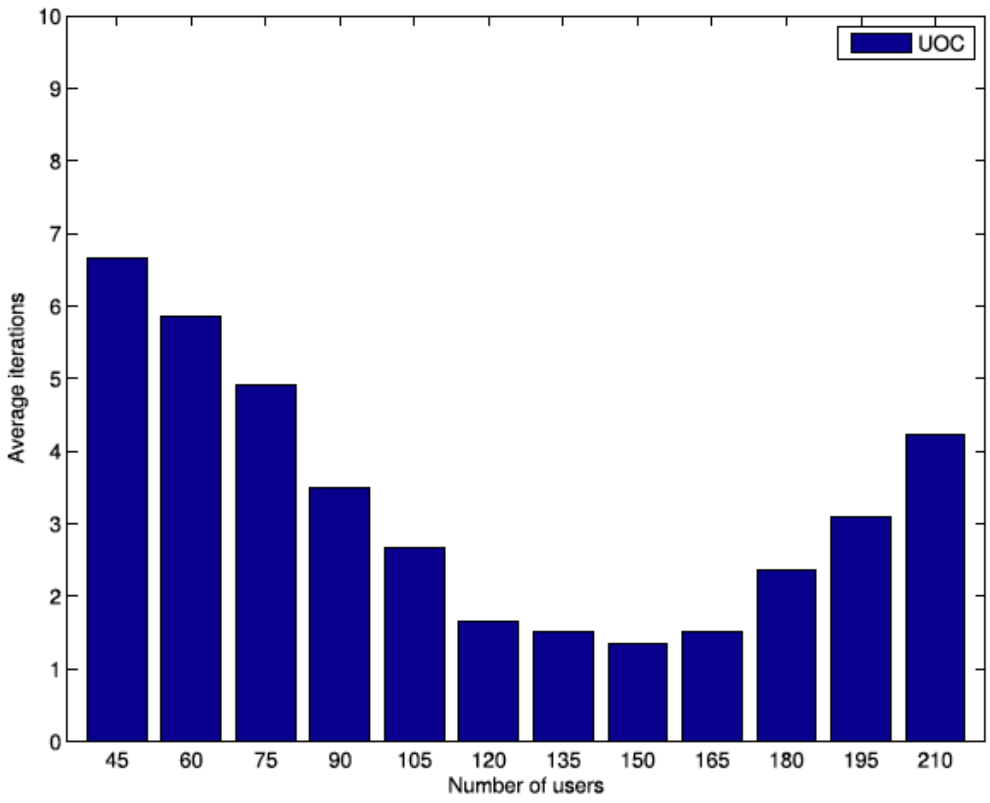


Performance Evaluation





Performance Evaluation



Conclusion

- This article has seen the radio and computational resources as discrete value
- Compare the QoS of our and their algorithm