Dynamic QoS-Aware Coalition Formation

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Outline

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Problem statement

- Heterogeneous environment
  - Resource constrained wireless devices
  - High performance neighbors
- Several work in computation offloading
  - To face heavy resource requirements in clients
- However
  - End-users do not have real influence on obtained QoS
  - Different users tolerate different QoS levels or combination choices
  - How to select the best neighbors according to user’s QoS requirements?
Proposed approach

- User specify **spectrum** of acceptable QoS levels in **request**
  - Through semantically rich QoS specification interface
  - Relative decreasing order expresses user’s preferences
- Underlying offloading mechanism splits application into tasks
- Formation of temporary **coalition** for service execution
  - Neighbors **cooperate** with resource-constrained device
  - Taking advantage of **global** available resources
  - **Offloading** computation
QoS specification interface

- QoS is often **multi-dimensional**
- Important to provide a **semantically rich** QoS specification
  - Users specify acceptable QoS levels
  - **Quality tradeoff** when resources are scarce

\[
QoS = \{ Dim, Atr, Val, DA_r, AV_r, Deps \}
\]

- Proposed scheme
  - **Defines** dimensions, attributes and values of a domain
  - **Relations** that maps
    - dimensions $\rightarrow$ attributes
    - attributes $\rightarrow$ values
  - **Dependencies** between attributes’ values
Service request

• Conflict
  ◦ Rich user’s request → accurate proposals’ evaluation
  ◦ User can’t specify utility of every quality choice
• Impose a preference order over dimensions, attributes and values
  ◦ Relative decreasing order expresses user’s preferences
• Example:
  1. Video Quality
     (a) frame rate: \{[10→5], [4→1]\}
     (b) color depth: \{3,1\}
  2. Audio Quality
     (a) sampling rate: 8
     (b) sample bits: 8
Coalition formation

- Objectives
  - Enable cooperation between neighbors
  - Address increasing demands on resources and performance
  - Maximize user’s influence on QoS provisioning
- Different groups of nodes → different service execution performance
- Distributed QoS optimization algorithm
  - Evaluation of multi-dimensional proposals
  - Selection of nodes offering service closer to user’s QoS preferences
Coalition formation

1. On the source node $N_i$, *QoS Provider* broadcasts **description** of each task $T_i$ as well as user’s **QoS constraints** $Q_i$

2. Every $N_j$ **formulates proposal** and replies to $N_i$ with proposal $P_j$ and its **local reward** $W_j$, resulting from its proposal acceptance

3. *QoS Provider* at $N_i$ **evaluates** all received proposals for each $T_i$ and **selects** the own that offers the values **closer to user’s QoS constraints** $Q_i$

4. $N_i$ offloads each $T_i$ to winning node(s)
Proposal’s formulation in neighbor node

- Proposal’s formulation centered in two principles
  - **User’s QoS constraints** expressed in request
  - **Local reward** of accepting new task

- Local QoS Provider
  - Recomputes QoS levels for new set of local tasks
    - Maximizing local reward
  - May involve degrading some tasks

- Guaranteeing user’s request
  - Receive service at **one** of requested QoS levels
Proposal’s formulation in neighbor node

- Each task $T_i$ have an associated set of user’s preferences
  - Presented in decreasing relative order
- Each $k$ QoS dimensions have $n$ possible attributes

1. Start by selecting the best QoS level in all $k$ dimensions, $Q_{kj}[0]$, for the new arrived task $T_a$

2. While the new set of tasks is not schedulable
   - For each task $T_i$ receiving service at $Q_{kj}[m] > Q_{kj}[n]$
     - Determine the utility decrease resulting from degrading attribute $j$ to $m + 1$
     - Find task $T_{min}$ whose decrease is minimum and degrade it to the $m + 1$’s level
Local reward

- Degree of **global** satisfaction

\[
    r = \begin{cases} 
        n & \text{if task is being served at } \mathbf{Q}_{kj}[0] \text{ for all dimensions} \\
        n - \sum_{j=1}^{n} \text{penalty}_j & \text{if } \mathbf{Q}_{kj}[m] > \mathbf{Q}_{kj}[0]
    \end{cases}
\]

- *penalty* is a parameter that decreases the reward value
  - Increases with distance to preferred values
Proposals’ evaluation in source node

- Relative decreasing order in user’s request
  - Imposes preferences
- Proposals evaluated **according to user’s preferences**

\[
\text{distance} = \sum_{k=1}^{n} w_k \times \text{dist}(Q_k)
\]

- For each dimension \( k \) evaluate
  - **Difference** between proposed and requested values

\[
\text{dist}(Q_k) = \sum_{i=1}^{\text{attr}_k} w_i \times \text{dif}(\text{Prop}_{ki}, \text{Pref}_{ki})
\]
Proposals’ evaluation in source node

- Degree of **acceptability** of proposed value
  - Compared to requested one

\[
\text{dif} = \begin{cases} 
\frac{\text{Prop}_{ki} - \text{Pref}_{ki}}{\max(Q_k) - \min(Q_k)} & \text{if continuous } Q_{ki} \\
\frac{\text{pos(Prop}_{ki} - \text{pos(Pref}_{ki})}{\text{length}(Q_k) - 1} & \text{if discrete } Q_{ki}
\end{cases}
\]
Conclusions

- Resource-constrained nodes may need to cooperate
  - To fulfill services at user’s QoS preferred values
  - Coalition’s performance is superior
- Users have different QoS requirements
  - Expressed through a semantically rich QoS specification
- Distributed service allocation
  - Multi-attribute proposals’ evaluation
  - Selecting nodes offering service closer to user’s preferences
- Proposals formulation for service execution
  - Local QoS optimization heuristic