ADMINISTRIVIA

- Assignment 2 out!
- Course Project
  - Project list by Oct 4
  - Form groups and submit project bids by Oct 11
  - Assigned project by Oct 15
  - Introductions due Oct 25
SETTING: FAIR SHARING

**Equal Share**

- 100% of allocation
- 33% of allocation
- 33% of allocation
- 33% of allocation

**Max-Min Share**

- Maximize the allocation for most poorly treated users

- Maximize the minimum

- 100% of allocation
- 20% of allocation
- 40% of allocation
- 40% of allocation
SLOT-BASED MODEL

Slot: Fixed quantity of CPU and memory

Example: Hadoop MapReduce
  Mapper: 2 CPU and 1 GB
  Reducer: 1 CPU and 2 GB

Allocate in units of slots
MOTIVATION: MULTI RESOURCES
DRF: MODEL

Users have a demand vector
<2, 3, 1> means user’s task needs 2 R1, 3 R2, 1 R3

Resources given in multiples of demand vector
i.e., users might get <4, 6, 2>
PROPERTIES

Sharing Incentive

Pareto Efficiency

Strategy Proof

Envy free
**PROPERTIES**

**Sharing Incentive**
User is no worse off than a cluster with 1/n resources

**Strategy Proof**
User should not benefit by lying about demands

**Pareto Efficiency**
Not possible to increase one user without decreasing another

**Envy free**
User should not desire the allocation of another user
**DRF: APPROACH**

<table>
<thead>
<tr>
<th>Dominant Resource</th>
<th>Dominant Share</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resource user has the <strong>biggest</strong> share of</td>
<td>Fraction of the dominant resource user is allocated</td>
</tr>
<tr>
<td>Total: &lt;10 CPU, 4 GB&gt;</td>
<td>E.g., for User 1 this is 25% or 1/4</td>
</tr>
<tr>
<td>User 1: &lt;1 CPU, 1 GB&gt;</td>
<td></td>
</tr>
<tr>
<td>Dominant resource is <strong>memory</strong></td>
<td></td>
</tr>
</tbody>
</table>
DRF: APPROACH

Equalize the dominant share of users

<table>
<thead>
<tr>
<th>User</th>
<th>Allocation</th>
<th>Dominant Share</th>
</tr>
</thead>
<tbody>
<tr>
<td>User1</td>
<td>&lt;0 CPU, 0 GB&gt;</td>
<td>0</td>
</tr>
<tr>
<td>User2</td>
<td>&lt;0 CPU, 0 GB&gt;</td>
<td>0</td>
</tr>
</tbody>
</table>

Total: <9 CPU, 18 GB>
User1: <1 CPU, 4 GB>
  dom res: **mem**
User2: <3 CPU, 1 GB>
  dom res: **CPU**
DRF: APPROACH

Total: <9 CPU, 18 GB>

User1: <1 CPU, 4 GB> per task
  <3 CPU, 12 GB> for 3 tasks
  dom res: mem
  dom share: 12/18 = 2/3

User2: <3 CPU, 1 GB>
  <6 CPU, 2 GB> for 2 tasks
  dom res: CPU
  dom share: 6/9 = 2/3
Whenever there are available resources:
Schedule a task to the user with *smallest dominant share*
Algorithm 1 DRF pseudo-code

\[
\begin{align*}
R &= \langle r_1, \ldots, r_m \rangle \quad \triangleright \text{total resource capacities} \\
C &= \langle c_1, \ldots, c_m \rangle \quad \triangleright \text{consumed resources, initially 0} \\
s_i \ (i = 1..n) &= \quad \triangleright \text{user } i\text{'s dominant shares, initially 0} \\
U_i &= \langle u_{i,1}, \ldots, u_{i,m} \rangle \ (i = 1..n) \quad \triangleright \text{resources given to user } i, \text{initially 0} \\
\end{align*}
\]

pick user \(i\) with lowest dominant share \(s_i\)

\(D_i \leftarrow \text{demand of user } i\text{'s next task}\)

if \(C + D_i \leq R\) then

\[
\begin{align*}
C &= C + D_i \quad \triangleright \text{update consumed vector} \\
U_i &= U_i + D_i \quad \triangleright \text{update } i\text{'s allocation vector} \\
s_i &= \max_{j=1}^{m} \{u_{i,j}/r_j\}
\end{align*}
\]

else

return \(\triangleright \text{the cluster is full}\)

end if
COMPARISON: ASSET FAIRNESS

Asset Fairness: Equalize each user’s sum of resource shares

Consider total of 70 CPUs, 70 GB RAM
U1 needs <2 CPU, 2 GB RAM> per task
U2 needs <1 CPU, 2 GB RAM> per task

Asset Fair Allocation:
U1: 15 tasks: 30 CPU, 30 GB (Sum = 60)
U2: 20 tasks: 20 CPU, 40 GB (Sum = 60)
COMPARISON: ASSET FAIRNESS

Asset Fairness: Equalize each user’s sum of resource shares

Violates Sharing Incentive

Consider total of 70 CPUs, 70 GB RAM
U1 needs <2 CPU, 2 GB RAM> per task
U2 needs <1 CPU, 2 GB RAM> per task

Sharing incentive?
Half of the cluster is 35 CPU, 35 GB RAM
U1:
U2:
COMPARISON: CEEI

CEEI: Competitive Equilibrium from Equal Incomes

- Each user receives initially $1/n$ of every resource,
- Subsequently, each user can trade resources with other users in a perfectly competitive market
- Nash solution: Maximize product of utilities across users
COMPARISON: CEEI

Total: <9 CPU, 18 GB>  User1: <1 CPU, 4 GB>  User2: <3 CPU, 1 GB>

\[
\max (x \cdot y) \quad \text{subject to} \quad x + 3y \leq 9, \quad 4x + y \leq 18
\]
CEEI: STRATEGY PROOFNESS

Total: <9 CPU, 18 GB>

User2 Before:
CEEI: 55% CPU, 9% mem

Total: <9 CPU, 18 GB>
User1: <1 CPU, 4 GB>
User2: <3 CPU, 1 GB>
User2: <3 CPU, 2 GB>
## COMPARISON

<table>
<thead>
<tr>
<th>Property</th>
<th>Allocation Policy</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Asset</td>
<td>CEEI</td>
<td>DRF</td>
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<tr>
<td>Sharing Incentive</td>
<td></td>
<td>✔</td>
<td>✔</td>
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<tr>
<td>Strategy-proofness</td>
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<td>✔</td>
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<td>Envy-freeness</td>
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<tr>
<td>Pareto efficiency</td>
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<td>✔</td>
<td>✔</td>
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<tr>
<td>Single Resource Fairness</td>
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<tr>
<td>Bottleneck Fairness</td>
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<tr>
<td>Population Monotonicity</td>
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<td>✔</td>
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<tr>
<td>Resource Monotonicity</td>
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<td>✔</td>
</tr>
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</table>

Table 2: Properties of Asset Fairness, CEEI and DRF.
DRF: Dominant Resource Fairness
Allocation policy for scheduling
Provides multi-resource fairness
Ensures sharing incentive, strategy proofness
DISCUSSION

https://forms.gle/n97b12Qcs8Xv3C6L6
What could be one workload / cluster scenario where DRF implemented on Mesos will NOT be optimal?
NEXT STEPS

Next Week: Machine Learning
Assignment 2 out!