MDP BASED OPTIMAL POLICY FOR COLLABORATIVE PROCESSING USING MOBILE CLOUD COMPUTING

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PROBLEM STATEMENT

Question:
• How can mobile phones collaborate with each other in order to complete a particular task in a more efficient manner?

Answer:
• Through a combination of Mobile Cloud Computing, Collaborative Networking, and Markov Decision Processes and look-up tables (of course)!
MOBILE CLOUD COMPUTING

Definition:
• A combination of cloud computing and mobile environments

✓ Useful for off-loading and sharing the various burdens related to complex computation and/or data storage.

✓ Offloading (or Cyber foraging) enables the mobile devices to offload tasks by leveraging unused sources on larger computers.
COLLABORATIVE NETWORKING

Definition:

• A collaborative network refers to an ad-hoc network system that is formed by users in close proximity to one another

✓ Pooling their resources

✓ Reducing overall load on a single device by using the other devices as mobile data relays.
MARKOV DECISION PROCESS

- MDP is a promising solution to combat calculation complexities as a mathematical framework
- Used to create decision tables, including outcomes which are partly random and partially dependent on user decisions
- MDP has a decision agent which checks the current state, $s$, repeatedly, take the decision to do action $a$ with probability $p$ which leads to the transition to state $s'$ including a reward, $r$
MARKOV DECISION PROCESS

MDP Parameters

• **S - State Space:** All possible states of the system, which are known to the decision-maker.

• **A - All possible actions that can be taken by the decision-maker**

• **R - Reward:** The reward for taking action \( a \) in a state \( s \).

• **P - Transition Probability:** The probability that an action \( a \) taken in state \( s \) at time \( t \) will result in a transition to state \( s' \) in time \( t + 1 \).
PROPOSED METHOD

Collaborative downloading

- There are *n* phones. Some ask other mobile devices to help in the downloading process.

Helpers can

- **Accept** the request and collaborate
- **Reject** the request to download the file
- **Relay** in order to send a file to a destination.
PROPOSED METHOD

1. Mobile node (Requester)
2. Finding potential Helpers based on battery level
3. Send requests
4. Identifying Requesters
5. Mobile node (Helper)
6. Find action A
7. Evaluate the Rewards
8. Compare two last rewards
9. Meet the criteria?
   - No
   - Yes
10. MDP Based Optimal Policy
11. Execute the action
REQUESTER SIDE
POLICY

• The requester’s decision is established on a threshold policy that is based on an individual phone’s determination of how conservative it wants to be in saving its charge for future communications.

• Each phone determines its $E_{th}$ (energy-threshold) and $E_i$ (current energy level) and sends it to service provider.

• The requesting phones use the server’s look up tables in order to choose which helper should send a request.

$$E = \begin{bmatrix} E_{i1} & E_{th1} \\ \vdots & \vdots \\ E_{in} & E_{thn} \end{bmatrix}$$
REQUESTER SIDE POLICY

If $E_i - E_{th} > e_o + e_d + e_f$, then its identification term will be saved at $E_{sel}$ matrix according to their conditions from excellent to fair

- $e_o$: Energy overhead for establishing collaboration
- $e_d$: Download energy cost
- $e_f$: Energy for helper to forward download

$$E_{sel} = \begin{bmatrix} k = excellent \\ \vdots \\ m = fair \end{bmatrix}$$
REQUESTER SIDE POLICY

- The matrix, $E$, is saved at the server and is updated each $T$ minutes.

- $E_{sel}$ will be sent to the requester in order to aid in choosing the helper phone.

- Messages are only sent to those potential helpers identified by the requestor.
HELPER SIDE POLICY

• The helper phone must decide to accept or reject the request that is presented by a requester.

• If the number of requests increases, the helper can choose one request according to calculated rewards.

• In an environment that includes several requests, a helper can accept one request and reject others or reject all of them based on the results of the MDP.
HELPER SIDE POLICY

MDP Parameters:

• \( A = \{ a_{i,j} \} \in \{ 0, 1 \} \)
• \( s \in S\{ P, N, T \} \)
  • \( P = \{ 1, 2, 3, \ldots, p_{\text{max}} \} \) in mw
  • \( N = \{ 1, 2, 3 \} \) number of bars or received signal code power (RSCP) level; and
  • \( T = \) Time since last recharge
**HELPER SIDE POLICY**

**Reward Components**

**Power Reward**

\[ f_p(s, a) = \frac{1}{1 + \exp(p_a)} \]

**Delay Reward**

\[ f_d(s, a) = \frac{1}{1 + \exp(d_a)} \]

**Transition Cost Function**

\[ h(s, a) = \begin{cases} H_{i,j} & i \neq j \\ 0 & i = j \end{cases} \]
HELPER SIDE POLICY

Reward Function

\[ f(s,a) = w_p \times f_p(s,a) + w_d \times f_d(s,a) \]

\[ \sum_m w_m = 1 \]

\[ r(s,a) = f(s,a) - h(s,a) \]
$C(r) = \ln(r) + 1$

- Should be scaled in credit domain ($\text{credit}_{\text{min}}, \text{credit}_{\text{max}}$).
- 1 is added to show each activity includes credit.
CREDIT EXCHANGE
RESULTS

Initial Results
• Impact of Helper Requests
• Impact of Power Reward
• Impact of Delay Reward

Simulation Results
• Simulation Network
• Rewards under Varying Power Consumption
• Credits Received under Varying Power Consumption
INITIAL RESULTS

A message with content of “Download Request” is sent to different Iphone 4s using a 3G network.
INITIAL RESULTS

Fixed Power Consumption

- Delay weight factor = 1/4
- Delay weight factor = 2/4
- Delay weight factor = 1

Graph showing fixed power consumption over delay (minutes) with different delay weight factors.
INITIAL RESULTS

Fixed Delay

![Graph showing power consumption and maximum reward value for different power weight factors. The graph compares power weight factor=1, power weight factor=3/4, and power weight factor=1/2. The x-axis represents power consumption, and the y-axis represents maximum reward value. The graph includes data points for each power weight factor, with distinct markers for each.]
INITIAL RESULTS

Relation between power, delay, and reward
RESULTS

Simulated Network

Area containing 4 Helper and 4 Requester
RESULTS

Maximum Reward Comparison

![Graph showing maximum reward comparison over delay with different power consumption settings.]
RESULTS

Credit Evaluation

![Graph showing credit evaluation over delay with different power consumption levels.](image)
SUMMARY AND CONCLUSION

• **Optimal policies** for mobile cloud computing on both the requester and helper sides are presented.

• The policy on requester side is based on differences of energy threshold and battery level of the helper mobile device.

• The policy on helper side is based on MDP and maximum calculated reward through iteration algorithm.

• Simulation shows less delay at responding to a request and less power consumption, resulting in higher amount of rewards.

• Potential future work may include applying SMDP instead of MDP in order to achieve more realistic results, evaluating larger networks, and other applications.
Thank you