Supplementary Information for "Joint Optimization of Communication, Caching, and Computing in Wireless Network Virtualization Based on Contract Theory"

Zexuan Yang‡, Biling Zhang†, and Li Wang‡,*
‡School of Electronic Engineering, Beijing University of Posts and Telecommunications, Beijing, P.R. China
†School of Network Education, Beijing University of Posts and Telecommunications, Beijing, P.R. China
*Corresponding author. Email: {yangzexuan,bilingzhang,liwang}@bupt.edu.cn

Algorithm 1: Joint 3C Resource Allocation Algorithm

Input: $V_n^{f_q}$, V_n^f, u_n
Output: Optimal contract $\left(\overline{R}_{n_\theta}^* \left(x_{n_\theta}^*, y_{n_\theta}^*\right), W_{n_\theta}^*\right), \theta \in \{1, \cdots, \vartheta\}$, caching strategy a^f

Step 1: The S-E algorithm
$K \leftarrow 0$;
for $temp = 0.01 : 0.01 : 10$ **do**
  $\overline{R}_{n_\theta} = temp \cdot R_\theta^{EXP}, \theta \in \{1, \cdots, \vartheta\}$;
  for $W_{n_\theta} = 0 : 0.2 : 25, \theta \in \{1, \cdots, \vartheta\}$ **do**
    if *IC&IR* **then**
      $ContractPairs \leftarrow (\overline{R}_{n_\theta}, W_{n_\theta}), \theta \in \{1, \cdots, \vartheta\}$;
      $K = K + 1$;
    end
  end
end
Step 2: Resource allocation based on optimal contracts and caching strategy
$U_{m,n_\theta}^{max} \leftarrow 0, \theta \in \{1, \cdots, \vartheta\}$;
for $k = 1 : K$ **do**
  for $\theta = 1 : \vartheta$ **do**
    $\overline{R}_{n_\theta} \leftarrow \overline{R}_{n_\theta}^k, W_{n_\theta} \leftarrow W_{n_\theta}^k$;
    if $f \in CacheSpace$ **then**
      if $q = Q$ **then**
        compute $\max\limits_{x_{n_\theta}} U_{m,n_\theta}^{Cache}, i > 1$;
      else
        compute $\max\limits_{x_{n_\theta}, y_{n_\theta}} U_{m,n_\theta}^{Cache}, i > 1$;
      end
    else
      if $j^f N \geq 1$ **then**
        $CacheSpace \leftarrow f$, $a^f \leftarrow 1$, $z^f \leftarrow 1$;
        if $q = Q$ **then**
          compute $\max\limits_{x_{n_\theta}} U_{m,n_\theta}^{Cache}, i = 1$;
        else
          compute $\max\limits_{x_{n_\theta}, y_{n_\theta}} U_{m,n_\theta}^{Cache}, i = 1$;
        end
      else
        if $q = Q$ **then**
          compare $\max\limits_{x_{n_\theta}} \sum\limits_{i=1}^{j^f N} U_{m,n_\theta}^{Cache}$ and $\max\limits_{x_{n_\theta}} j^f N \cdot U_{m,n_\theta}^{\text{N-Cache}}$;
          if $a^f == 1$ **then**
            $CacheSpace \leftarrow f$, $z^f \leftarrow 1$;
          end
        else
          compare $\max\limits_{x_{n_\theta}, y_{n_\theta}} \sum\limits_{i=1}^{j^f N} U_{m,n_\theta}^{Cache}$ and $\max\limits_{x_{n_\theta}, y_{n_\theta}} j^f N \cdot U_{m,n_\theta}^{\text{N-Cache}}$;
          if $a^f == 1$ **then**
            $CacheSpace \leftarrow f$, $z^f \leftarrow 1$;
          end
        end
      end
    end
    if $U_{m,n_\theta}^{max} \leq U_{m,n_\theta}$ **then**
      $U_{m,n_\theta}^{max} \leftarrow U_{m,n_\theta}, \overline{R}_{n_\theta}^* \leftarrow \overline{R}_{n_\theta}, W_{n_\theta}^* \leftarrow W_{n_\theta}$;
    end
  end
end

Lemma 1. For video file f, if $j^f N \geq 1$, we have $a^f = 1$.

proof: Since $\frac{c_{ca} V_n^f}{j^f N} \ll \frac{\beta V_n^f}{j^f N}$, if (12)$\geq 0$, we have $\beta V_n^f \geq \frac{\beta V_n^f}{j^f N}$. For video with a high request rate, $j^f N \geq 1$, which leads that the function (12) is greater than zero and $a^f = 1$.