User-Aware Cell Switch-Off Algorithms

Ibrahim Aydin, Halim Yanikomeroglu, Ümit Aygölü
Istanbul Technical University, Istanbul, Turkey

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Outline

- Introduction / motivation
- Basics of CSO
- Literature
- Contribution
- Performance evaluation
- Conclusion

Introduction / motivation (1)

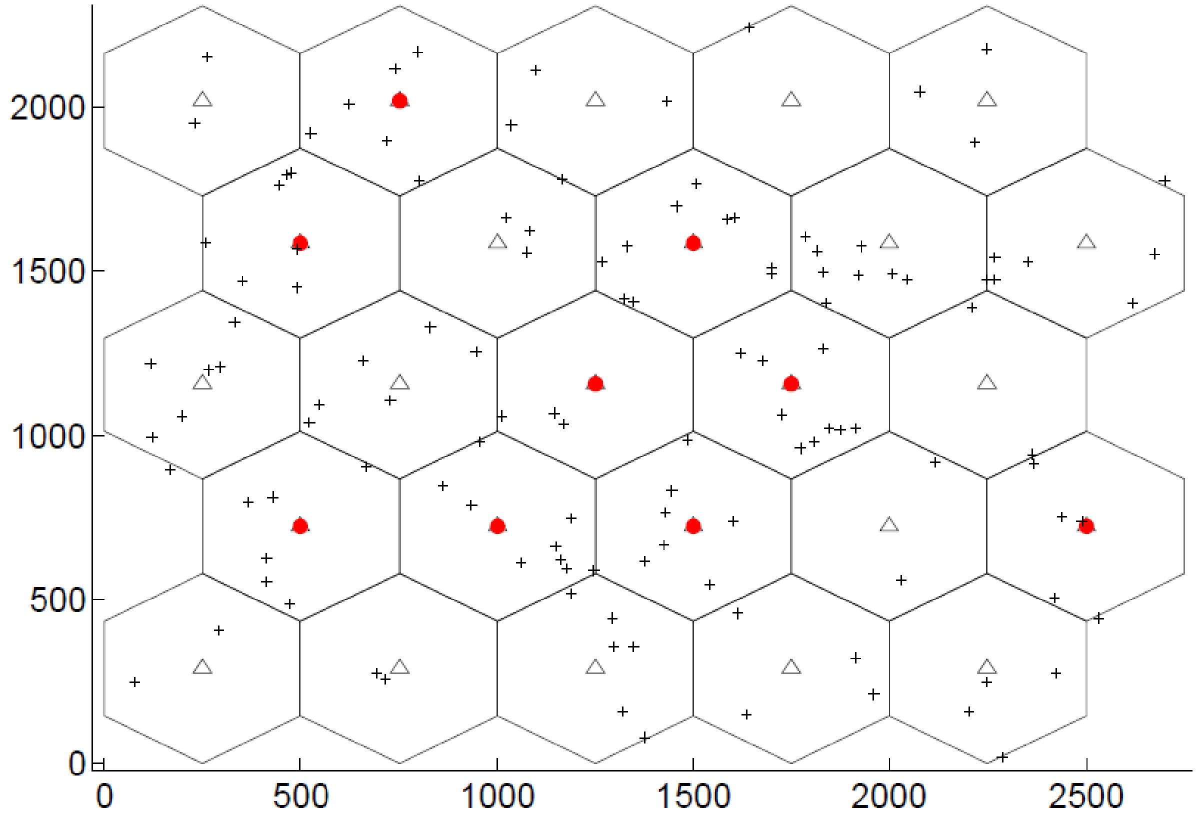
- Green communication has become a hot research area:
  - Environmental awareness
  - Increased cost of energy
  - Battery life issue of mobile devices
- Forward 5G
  - Higher data rates
  - More BSs
  - More mobile devices

Introduction / motivation (2)

- BSs are the main energy consumers
  - 50% to 80% of the energy consumption in cellular networks takes place in the BSs
- The power consumption, which is independent from transmission, dominates the total consumption
  - BSs consume at zero load about 60-80% of the energy consumption at full load
- Significant imbalance of the BS traffic loads
  - 10% of the BSs carry about 50-60% of the aggregate traffic load .

Cell switch-off (CSO)

CSO applied cellular network



Basics of CSO

- Two main approaches in the CSO concept:
  - **Deterministic** approach where the CSO is performed according to the instantaneous traffic information
  - **Statistical** approach where the statistical behavior of traffic is used to execute the CSO algorithms
- According to management of CSO procedure:
  - **Centralized** algorithms: excessive signaling overhead but better performance.
  - **Distributed** algorithms: less signaling overhead but some performance loss

Literature

- Literature about CSO
  - Decrease the power consumption of the whole network
  - Switch-off BSs as much as possible without any QoS degradation
  - Just the downlink side is considered
  - Power consumption of the UTs is not investigated
    - Switching off BSs for downlink energy efficiency may result in an uplink energy inefficiency

Contribution

- We propose a heuristic CSO algorithm
  - Achieves energy and cost reduction
    - Switch-off BSs as much as possible
  - Battery lives of UTs less affected
    - Takes into account the power consumption of UTs while determining switching-off BSs.
  - Downlink and uplink sides considered
  - We call the proposed algorithm as the **user-aware CSO algorithm**.

System model

- Homogeneous network
- UTs are uniformly distributed
- Full buffer traffic model
- Deterministic approach
  - We take a snapshot of the network at a certain time to determine which BSs will be closed.
- No interference management
  - A worse case scenario
  - Average interference is considered
- Constant rate requirement for DL and UL

Power control (1)

- Power control for DL and UL
- Optimum solutions are not simple
  - Exhaustive iterative algorithms
- Optimization problem for DL:

$$\begin{aligned} &\text{minimize} && P_m^D \\ &\text{subject to} && B_m^D \leq B_{BS} \end{aligned}$$

- Non-convex problem
  - Analyzing KKT conditions give a suboptimum result
  - The results are better than some simple methods, i.e. Equal power allocation, uniform power allocation over BW

Power control (2)

Algorithm 1 Power Allocation Algorithm

Input: Received signal powers of UTs of BS m

Output: $B^D_{m,i}, P^D_{m,i} \quad \forall i \in S_m$

$k \leftarrow 1$

Loop

Select the UT with the minimum received power.

Allocate k subchannel for this UT, then find λ using (6).

Determine the allocated bandwidths for all the UTs from (6) by using the obtained λ.

Determine the allocated powers for all the UTs according to (2).

Check the summation of allocated bandwidths ($B^D_m = \sum_{i \in S_m} B^D_{m,i}$).

if ($B^D_m < B_{BS}$) **then**

$k \leftarrow k + 1$

else

Change the current bandwidth and power allocation with the bandwidth and power allocation of the previous loop.

Allocate the free bandwidth ($B_{BS} - B^D_m$) to the UT which has minimum received power and find the allocated power for this UT according to (2).

break Loop

end

End Loop

User-aware CSO algorithm

- Collect the information about network
- Perform resource allocation
- Sort the BSs
  - **Sorting criterion:** the increment of the sum power of UTs when a BS is switched off
- Switch-off BSs one by one
- Terminate when no BS can be switched-off without violating QoS constraint
  - A certain rate of UTs is allowed to be outage (2%)

Algorithm 2 User-Aware CSO Algorithm

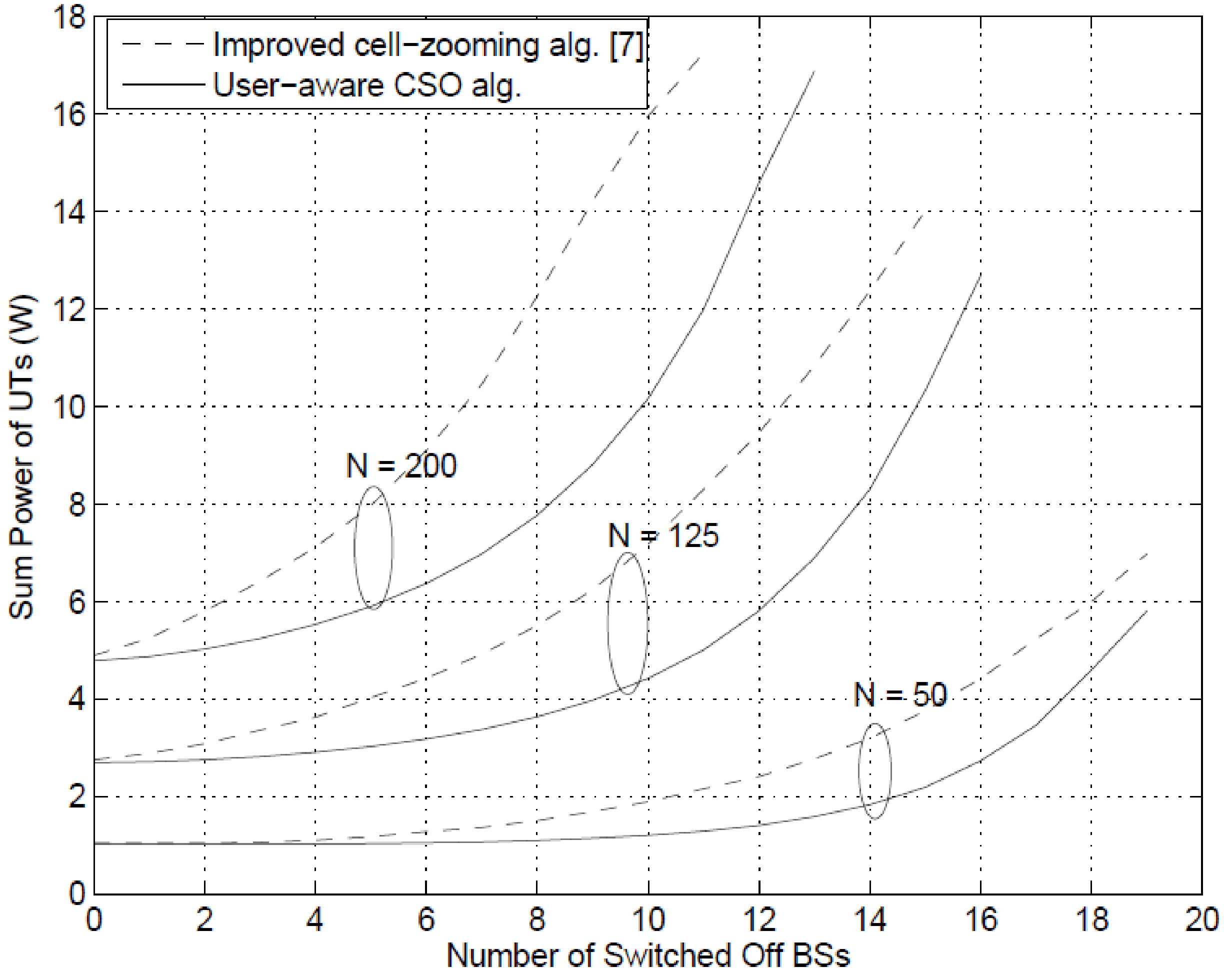
Input: $\mathbf{W}$
Output: $\mathbf{X}$, $\mathbf{B^D}$, $\mathbf{B^U}$, $\mathbf{P^D}$, $\mathbf{P^U}$

$\mathbf{X} \leftarrow \mathbf{0}$
$\mathbf{P_{dif}} \leftarrow \mathbf{0}$
$T \leftarrow$ Set of all the BSs.
Associate each UT i with BS m which has the highest $w^D_{m,i}$.
Update $\mathbf{X}$.
Find $\mathbf{B^D}$, $\mathbf{P^D}$, $\mathbf{B^U}$ and $\mathbf{P^U}$ using Algorithm 1 (Power control algorithm).
while $T \neq \emptyset$ **do**
    for each BS $j \in A$ **do**
        Assume BS j is switched-off.
        Re-associate S_j with the neighbour BSs which have the highest received signal power.
        Find $\mathbf{B^D}$, $\mathbf{P^D}$, $\mathbf{B^U}$ and $\mathbf{P^U}$ by the help of Algorithm 1.
        Calculate the sum of UTs power.
    end
    Update $\mathbf{P_{dif}}$.
    Select cell m with smallest $\mathbf{P_{dif}}$.
    Re-associate S_m with the neighbour BSs which have the highest received signal power.
    if (outage constrained is satisfied) **then**
        Switch-off BS m.
        Update $\mathbf{X}$.
        Update $\mathbf{B^D}$, $\mathbf{P^D}$, $\mathbf{B^U}$ and $\mathbf{P^U}$ using Algorithm 1.
        $A = A - \{m\}$.
        $T = T - \{m\}$.
    else
        $T = T - \{m\}$.
    end
end

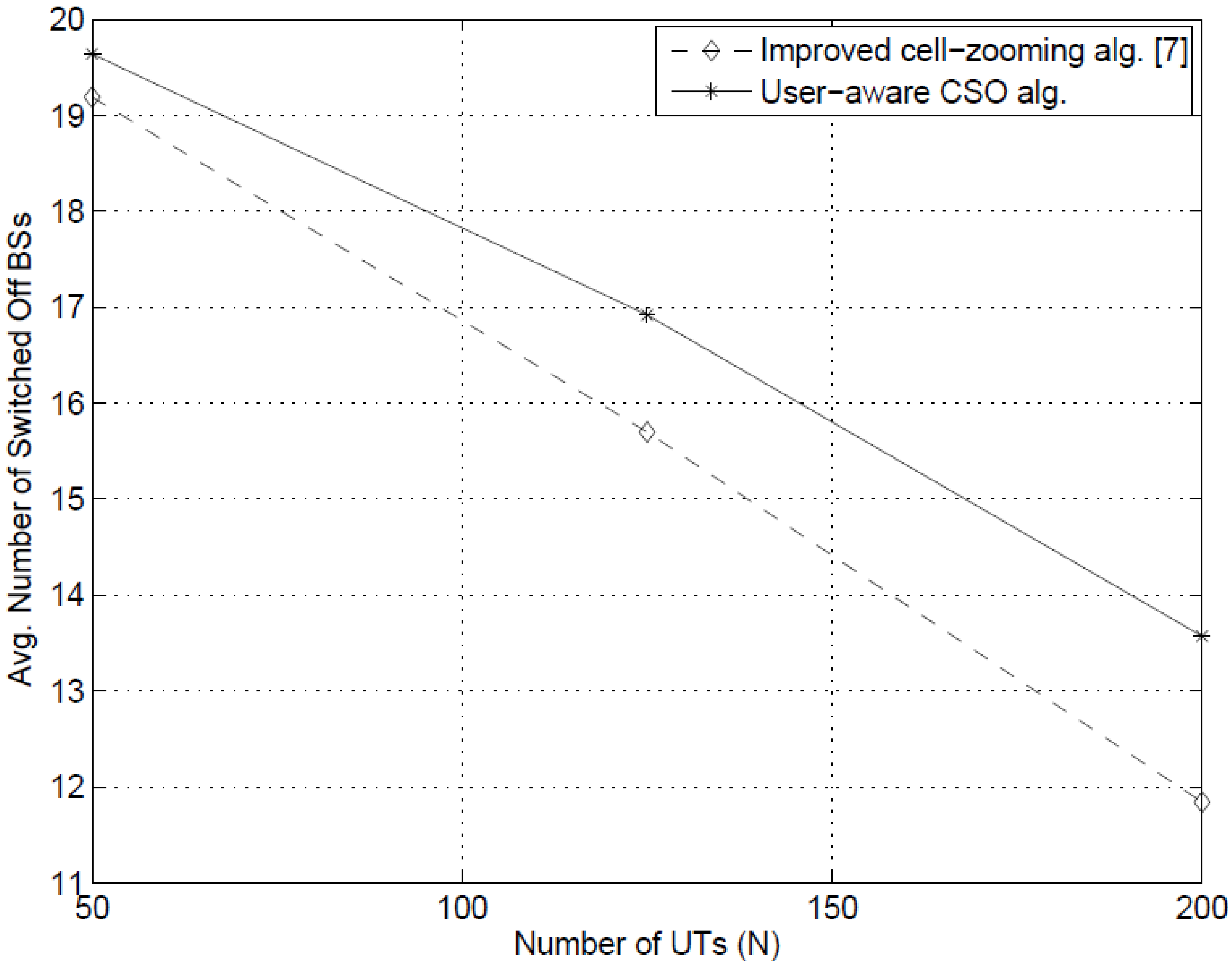
System parameters

Total bandwidth of a BS (B_{BS})	5 MHz
BS maximum transmission power (P_{BS})	5 W
UT max. transmission power ($P_{\max}^{U}$)	250 mW
Path loss model	$30 + 36.7\log(d) + X_{\sigma}$
Standard deviation of X_{σ} (σ)	8 dB
UT downlink data rate (R_{dl})	500 kbps
UT uplink data rate (R_{ul})	300 kbps
Thermal noise (N_0)	-174 dBm/Hz
Noise figure (N_f)	10 dB
Inter BS distance	500 m
Min. distance between a UT and a BS	10 m
Number of BSs (M)	25
Number of UTs	50, 125, 200
Max. outage probability (total)	2%
α and β in (1)	3.1 W and 53 W

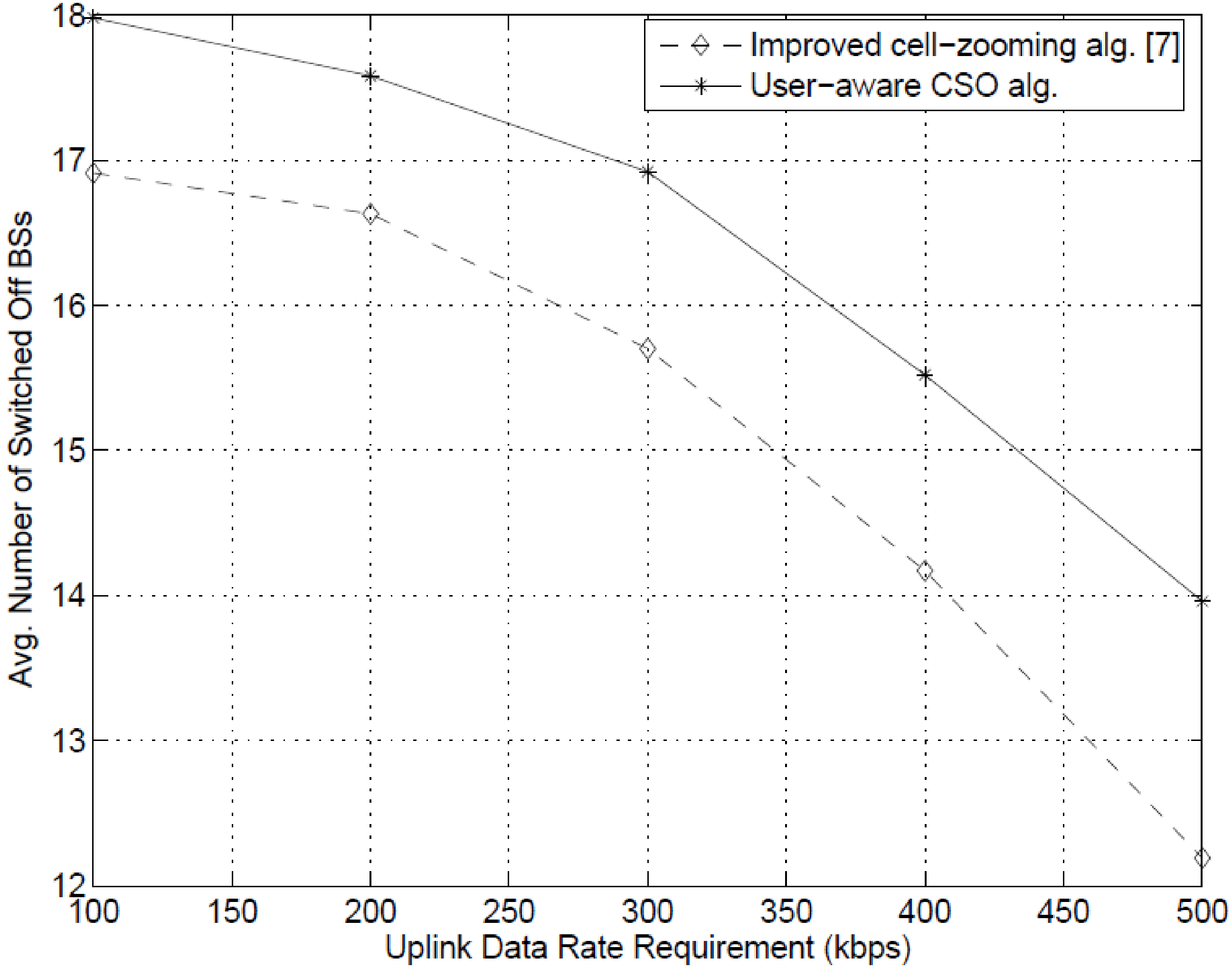
Performance evaluation (1)



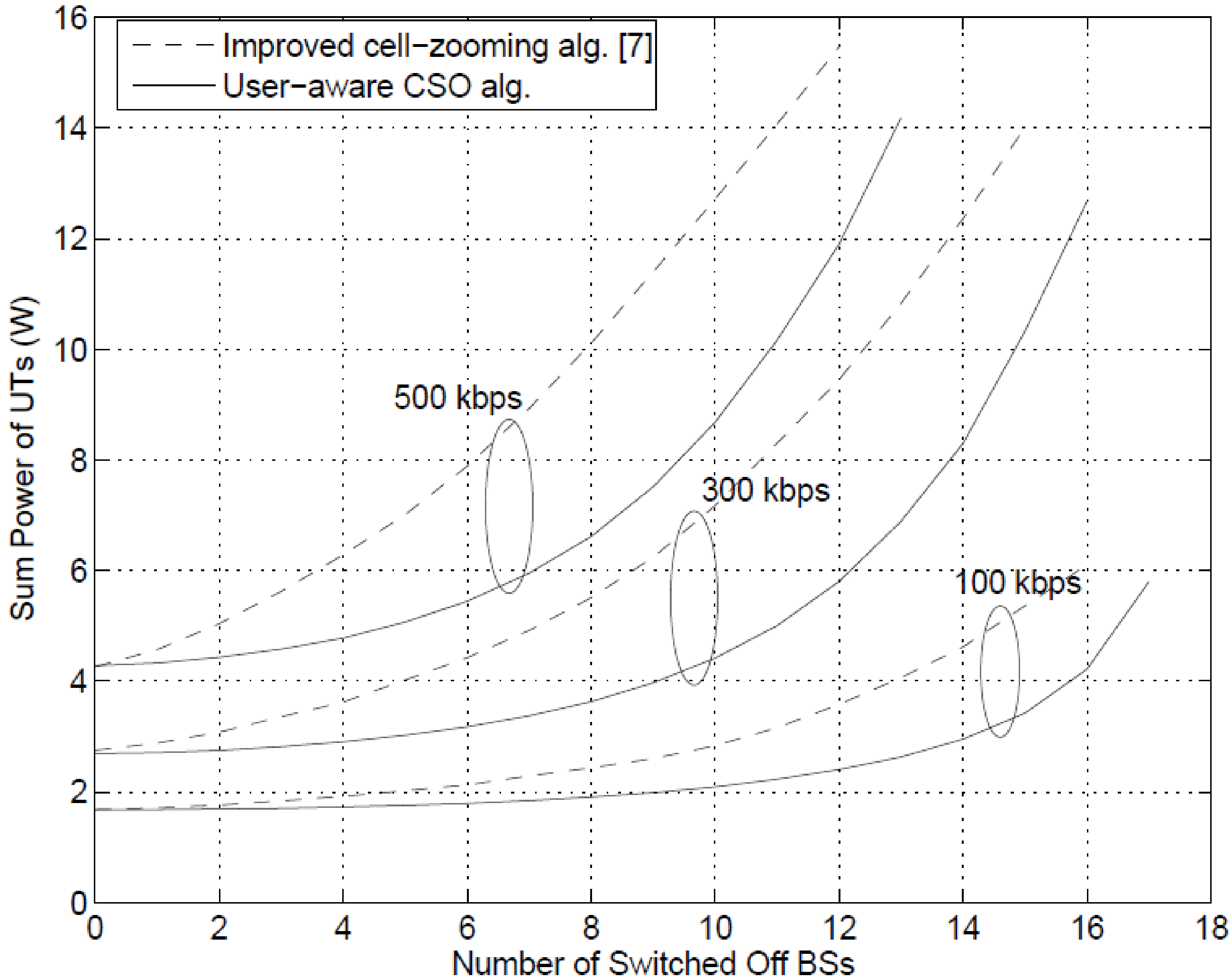
Performance evaluation (2)



Performance evaluation (3)



Performance evaluation (4)



Conclusion

- We proposed a user-aware CSO algorithm where the power consumption of UTs are minimally impacted by switching off BSs
- The user-aware CSO algorithm is a heuristic and simple algorithm
- The user-aware CSO algorithm achieves up to around 40% less power consumption of UTs in comparison to the improved cell-zooming algorithm
- This study shows that to investigate the power consumption of UTs is crucial for CSO algorithms.

Questions??

Thank You