Towards Energy Efficiency in Ultra Dense Networks

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03/May/2019

UGRP

Background

- Multiple performance requirements
  - Thousand traffic volume
  - Multi-gigabit per second data rates
  - Communication devices on the other of hundreds of millions

- 5G relevant technology
  - UDN
  - MMwave
  - Massive MIMO

Motivation

- UDN consist of a massive number of BSs
  - Macro-cell BSs
  - Small-cell BSs

- Energy consumption of UDN is a critical issue
  - BSs consume more than 80% of energy in a network

- Energy efficiency scheme on the BS can be categorized as the BS energy consumption minimization

Problem Solving Idea

- BSs set sleep mode when no active UEs are connected

- For QoS, set some constraint
  - Coverage of Ues
  - Capacity of small-cell BSs
  - Data rate of UEs

Network Modeling

- UDN consists of macro cells, small cells and Ues
  - Macro cells: hexagonally deployed as the traditional cellular network
  - Small cells: deployed in outdoor open space(e.g. 1 km^2)

- Small cells have uniform configuration
  - Communication distance
  - Transmission power
  - Connection capacity

- UEs are randomly distributed in the network

Problem Formation

- m small cells and n UEs

- Status information of awake/sleep mode equation

$$S_B = [s_1, \cdots, s_i, \cdots, s_m], i \in [i, m]$$

$$s_i = \begin{cases} 1 \; awake \\ 0 \quad sleep \end{cases}, i \in [i, m]$$

Problem Formation

- Connectivity information of UEs and BSs

BS 1

BS n

$$W = \begin{bmatrix} w_{1,1} & \cdots & w_{1,j} & \cdots & w_{1,n} \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ w_{i,1} & \cdots & w_{i,j} & \cdots & w_{i,n} \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ w_{m,1} & \cdots & w_{n,j} & \cdots & w_{m,n} \end{bmatrix}, w_{i,j} = \begin{cases} 0 & F_i \; not \; connect \; to \; U_j \\ 1 & F_i \; connect \; to \; U_j \end{cases}$$

User

BS

User가 BS랑 연결된 갯수

Problem Formation

- Objective function

$$\sum_{i=1}^{m} E \cdot s_i \ (1)$$

- Constraint

$$\forall j \in (1, n), \sum_{i=1}^{m} w_{i,j} = 1 \ (2)$$

$$\forall j \in (1, n), \sum_{i=1}^{m} w_{i,j} \sqrt{\left(X_{B_i} - X_{U_j}\right)^2 + \left(Y_{B_i} - Y_{U_j}\right)^2} < D \ (3)$$

$$\forall j \in (1, n), \sum_{i=1}^{m} B \cdot w_{i,j} < C \ (4) \ (B \ is \ \ UE \ bandwidth, C \ is \ capacity \ of \ BS)$$

$$B \geq R \ (5) \ (R \ is \ the \ UE \ demand \ data \ rate)$$

Algorithm

Algorithm 1: BS awake/sleep control algorithm

Input: $w = zeros(N)$, $W = zeros(N)$, W stores the connectivity information, N demonstrates the equal number of BS and UE, A stores the distances of BS to each UE, R_{UE} is the communication range of UE, C_{BS} is the BS capacity, $MinR$ constraints the number of UE connected to BS

Output: $Result$

```
CR = size(W) — 행: CR(1), 열: CR(2)
if CR(2) ≠ 1 then
    for i = 1 : CR(1) do
        if (A(i, N + 1 − CR(2))) ≤ R_UE(i) then
            W(i, N + 1 − CR(2)) = 1
            w = zeros(CR(1), CR(2) − 1)
            Algorithm 1(w, W, A, R_UE, C_BS)
            w(i, 1) = 0
            W(i, N + 1 − CR(2)) = 0
else
    for j = 1 : CR(1) do
        if (A(j, N + 1 − CR(2)) ≤ R_UE(j)) then
            W(j, N + 1 − CR(1)) = 1
            if (∑(W, 1)) ≤ C_BS then
                if (length(find(∑(W, 1))) < MinR) then
                    Result=W
                    MinR = length(find(∑(W, 1)))
            W(j, N + 1 − CR(1)) = 0
return Result
```

Evaluation Method

- Uniform and non-uniform distribution

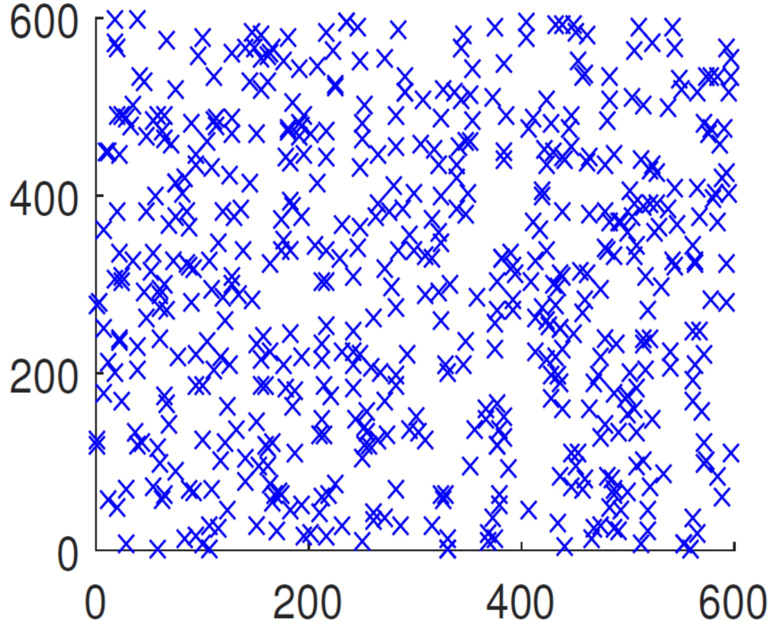

Fig. 1: UE with uniform distribution

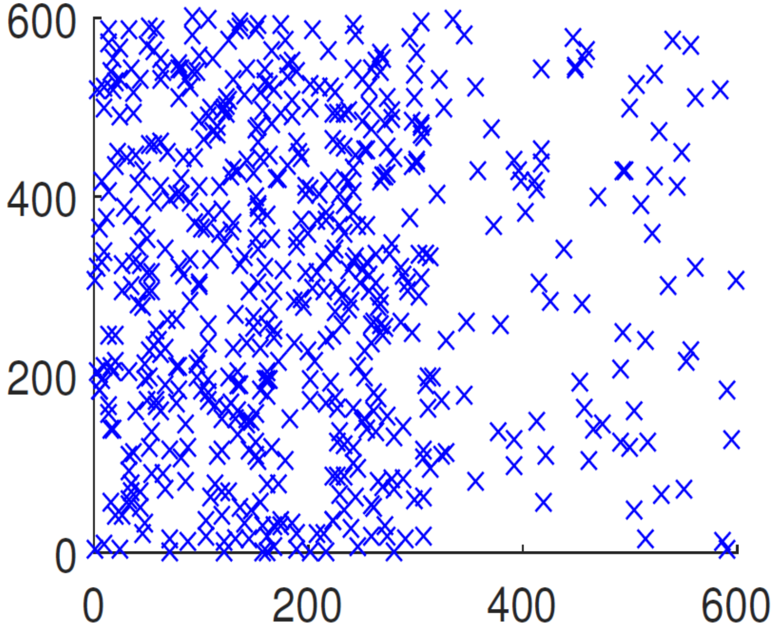

Fig. 4: UE with non-uniform distribution

Evaluation Method

- UE mobility model

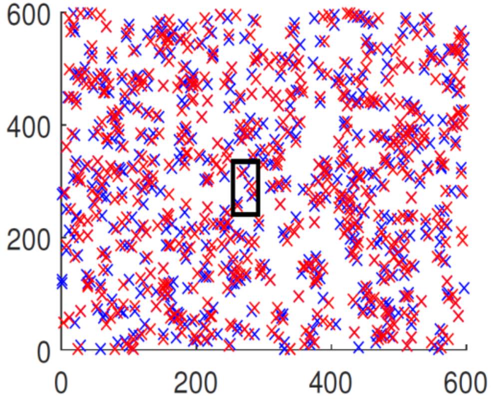

Fig. 2: UE movement with random walk

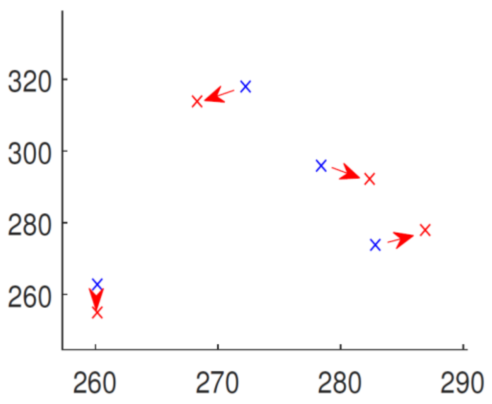

Fig. 3: An example of the UE movement

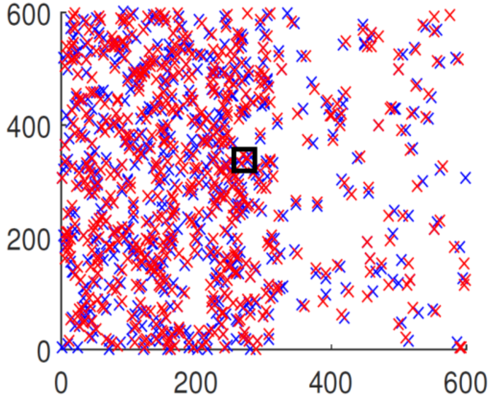

Fig. 5: UE movement with random walk

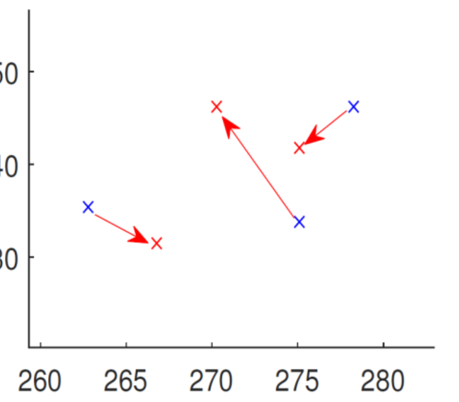

Fig. 6: An example of the UE movement

Evaluation Model

- Scenario 1
  - UE is uniformly distributed in network
  - UE’s mobility model is a random walk

- Scenario 2
  - UE is non-uniformly distributed in network
  - UE’s mobility model is random walk

- Scenario 3
  - Network consists of different BS-UE density ratio where UE is uniformly distributed in the network
  - UE’s mobility model is random walk

Result

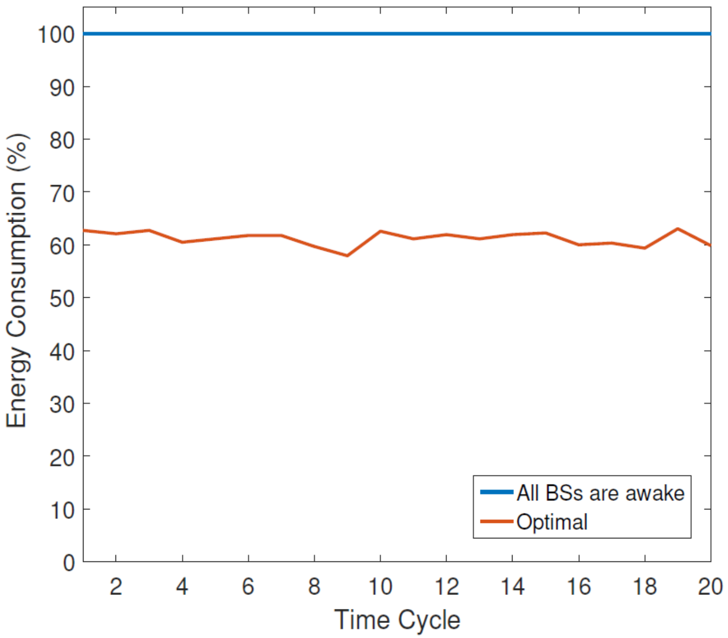

Fig. 7: Energy efficiency (uniform distribution)

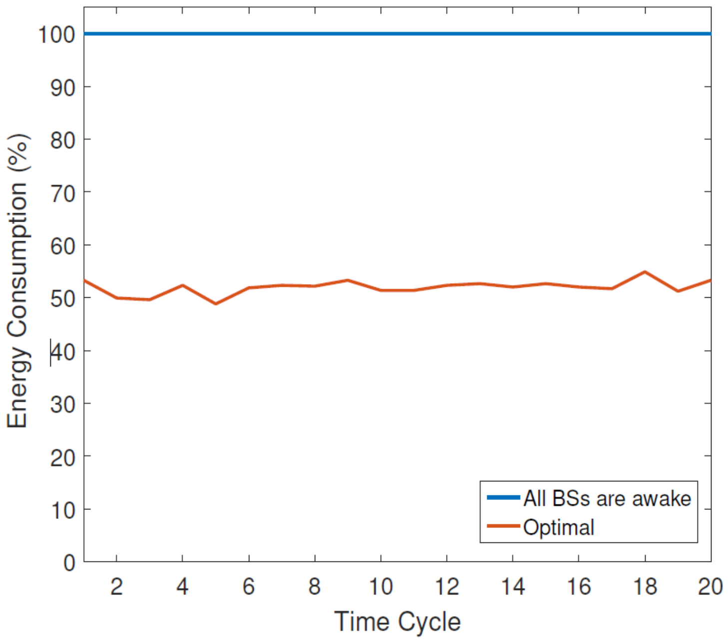

Fig. 8: Energy efficiency (non-uniform distribution)

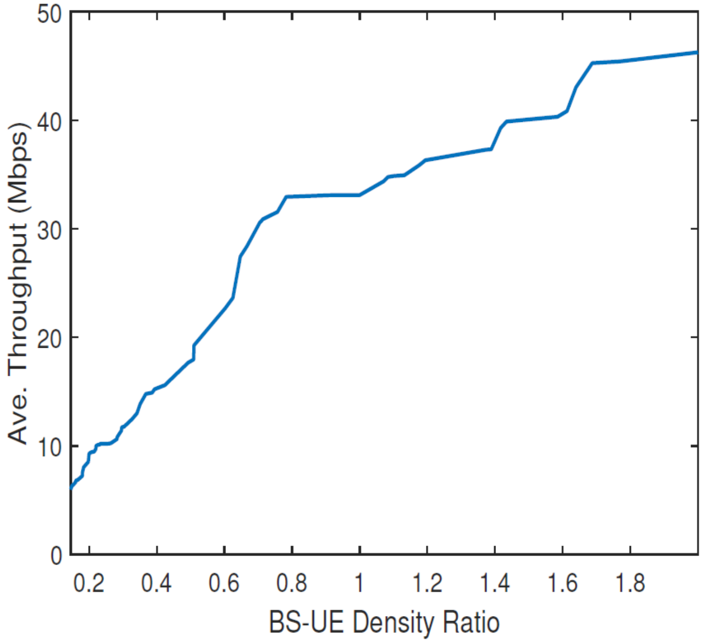

Fig. 9: Network throughput versus BS-UE density ratio

≈ data rate

Conclusion

- UDN by designing an approach to optimally enable the small-cell BS awake/sleep mode scheduling

- problem of achieving the tradeoff between energy efficiency and network performance as an optimization problem

- Propose the optimazation algorism to solve the problem

- energy efficiency of the UDN is improved significantly in various UE distribution and UE mobility scenarios, while at the same time, the network performance is guaranteed.

Any Questions?

THANK YOU

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