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BS sleeping strategy for energy-delay tradeoff in wireless-backhauling UDN

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Medical Robotics

Brain Science

Green Energy

Emerging Materials

Information & Communication Engineering

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Outline

- **Part 1 - Introduction**
- **Part 2 – System model and operation modes**
- **Part 3 – System energy consumption and packet delay**
- **Part 4 – Algorithm**
- **Part 5 – Result and conclusion**

Part 1

Introduction

BS increase

-> power consumption increase

-> delay decrease (Vice versa)

Tradeoff!!

Introduction

Key words

· packet delay
· energy consumption
· radio access and wireless-backhauling
· BS sleeping strategy

Part 2

System model and operation modes

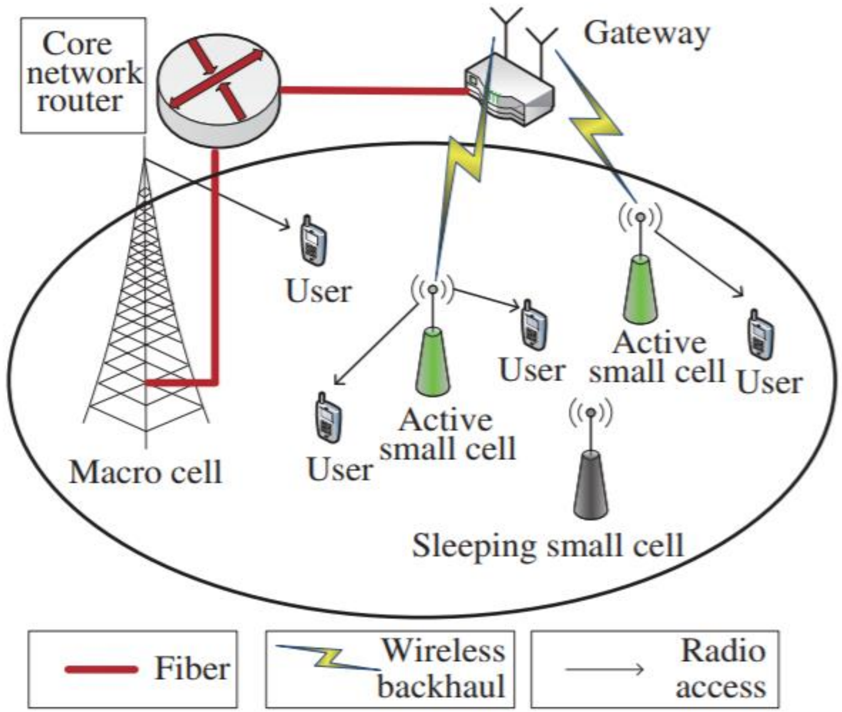


Figure 1 (Color online) Network model for two-tier wireless-backhauling UDN.

user small cell

Each locations are distributed according to independent PPP
with ($\lambda u > \lambda s > \lambda g$, $\lambda u > \lambda s > \lambda m$)

user small cell? gateway? macrocell

System model and operation modes

Transmission model

To prevent UE with low SIR from occupying too much resource, packet transmission is successful only if the SIR of UE is above threshold

BS sleeping ratio θ= Noff/Ns

$$\mathrm{Pr}_{\mathrm{SUE}}(\theta) = \frac{(1-\theta)\lambda_s (A_b P_{\mathrm{st}})^{\frac{2}{\alpha}}}{(1-\theta)\lambda_s (A_b P_{\mathrm{st}})^{\frac{2}{\alpha}} + \lambda_m {P_{\mathrm{mt}}}^{\frac{2}{\alpha}}},$$

$$\mathrm{SIR} = \frac{P_t h_{x_0} \|x_0\|^{-\alpha}}{\sum_{x\in\phi\backslash\{x_0\}} P_t h_x \|x\|^{-\alpha}},$$

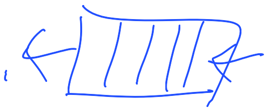
by 레일리 fading

System model and operation modes

UGRP를 위해서는 크게 중요하지는 않는 듯

Queue model

queue – 선입선출 FIFO.



cf) stack

Last in First out

네트워크에서는 stack 같은 없음.

Markov

general distribution

one server

We use M/G/1 queueing model to analyze packet delay for wireless-backhauling UDNs

The queue length can be defined as the number of packets waiting for transmission in the buffer of BS

System model and operation modes

Power consumption model

$$\bar{P}_M = (1-\bar{\xi}_m(\theta))\bar{P}_{m0}+\bar{\xi}_m(\theta)(\bar{P}_{m0}+\Delta p_m P_{\mathrm{mt}})$$

$$\bar{P}_A = (1-\bar{\xi}_s(\theta))\bar{P}_{s0}+\bar{\xi}_s(\theta)(\bar{P}_{s0}+\Delta p_s P_{\mathrm{st}})$$

The queue length can be defined as the number of packets waiting for transmission in the buffer of BS

System model and operation modes

Part 3

System energy consumption and packet delay

System energy consumption

If $|\mathcal{A}|$ denotes the area of the entire network, then the number of gateways, macro cells, and small cells is given by $\lambda_g|\mathcal{A}|$, $\lambda_m|\mathcal{A}|$, and $\lambda_s|\mathcal{A}|$, respectively. Now, the average energy consumption of the system can be represented by

$$\bar{P}(\theta) = |\mathcal{A}|(\lambda_g \bar{P}_G + \lambda_m(\bar{P}_{m0} + \bar{\xi}_m(\theta)\Delta p_m P_{\mathrm{mt}}) + (1-\theta)\lambda_s(\bar{P}_{s0} + \bar{\xi}_s(\theta)\Delta p_s P_{\mathrm{st}}) + \theta\lambda_s \bar{P}_S), \quad (3)$$

System energy consumption and packet delay

ISC

Part 4

Algorithm

1. Queue-aware sleeping strategy

The small cell with the shortest average queue length is turned off to save energy

$$Q_k(t) = \max\{0, Q_k(t-1) - R_k(t)\triangle t + A_k(t)\},$$

Rk(t) , the average transmission rate of a small cell k at the t-th time slot

Ak(t) , the number of packets arriving in the small cell k at the t-th time slot

Algorithm

2. channel-queue-aware sleeping strategy

Average queue length depends on not only the packet arrival rate, but also the BS service rate

Complexity of algorithm1 and 2 is same

Algorithm

Algorithm 1 Queue-aware sleeping strategy

Input: SBS set $\mathcal{B}_S$, MBS set $\mathcal{B}_M$, UE set $\mathcal{U}$, θ^*, T, Δt, $\forall i \in \mathcal{U}$, $\forall j \in \{\mathcal{B}_S, \mathcal{B}_M\}$, $\forall k \in \{\mathcal{B}_S\}$.

Output: Optimal state set of SBS $\mathcal{S}^*$.

```
Initialize: all MBSs and SBSs are active, S = (1, 1, 1, ..., 1) and n = 1;
Calculate N_off according to (33);
Select the serving BS j* = arg max{RSRP_j}_{j ∈ {B_S, B_M}} for each UE i;
Find the set of UEs U_j that can be served by each BS j;
for each t ∈ [1, T] do
    Calculate transmission rate R_k(t), update queue length according to (34), for small cell BS k;
end for
Calculate Q̄_k = (Σ_{t=1}^{T} Q_k(t)) / T for each small cell BS k;
while n ⩽ N_off then
    for each small cell BS k do
        if S(1, k) = 1 and k = min_{k ∈ B_S} {Q̄_k};
            S(1, k) = 0, assign UEs in U_k to neighboring BSs;
        end if
    end for
    n = n + 1;
end while
```

Algorithm 2 Channel-queue-aware sleeping strategy

Input: SBS set $\mathcal{B}_S$, MBS set $\mathcal{B}_M$, UE set $\mathcal{U}$, θ^*, T, Δt, $\forall i \in \mathcal{U}$, $\forall j \in \{\mathcal{B}_S, \mathcal{B}_M\}$, $\forall k \in \{\mathcal{B}_S\}$.

Output: Optimal state set of SBS $\mathcal{S}^*$.

Initialize: all MBSs and SBSs are active, $\mathcal{S} = (1, 1, 1, \ldots, 1)$ and $n = 1$;

Calculate N_{off} according to (33);

Select the serving BS $j^* = \arg\max\{\text{RSRP}_j\}_{j \in \{\mathcal{B}_S, \mathcal{B}_M\}}$ for each UE i;

Find the set of UEs $\mathcal{U}_j$ that can be served by each BS j;

for each $t \in [1, T]$ **do**

  Calculate transmission rate $R_k(t)$, update queue length according to (34), for small cell BS k;

end for

Calculate $\bar{Q}_k = \frac{\sum_{t=1}^{T} Q_k(t)}{T}$ and $\bar{R}_k = \frac{\sum_{t=1}^{T} R_k(t)}{T}$ for each small cell BS k;

while $n \leqslant N_{\text{off}}$ **then**

  for each small cell BS k **do**

    if $\mathcal{S}(1, k) = 1$ and $k = \min_{k \in \mathcal{B}_S}\{\bar{Q}_k \bar{R}_k\}$;

      $\mathcal{S}(1, k) = 0$, assign UEs in $\mathcal{U}_k$ to neighboring BSs;

    end if

  end for

  $n = n + 1$;

end while

bandwith

arrival rate

Table 1 System parameters

Parameter	Value	Parameter	Value	Parameter	Value	Parameter	Value
λ_g	5×10^{-6}	P_{s0}	4.8 W	W_b	20 MHz	λ	0.5 s^{-1}
λ_m	1×10^{-5}	P_{m0}	10 W	W_m	10 MHz	Δp_m	10
λ_s	5×10^{-5}	P_S	2.4 W	W_s	10 MHz	Δp_s	8
λ_u	2×10^{-4}	P_G	100 W	l	0.1 MB	β	5

packet size

threshold

Part 5

Results and conclusion

small cell interference 때문에, sleep↑ → delay↓

Mean packet delay

BS 가 너무 줄어들면 delay↑

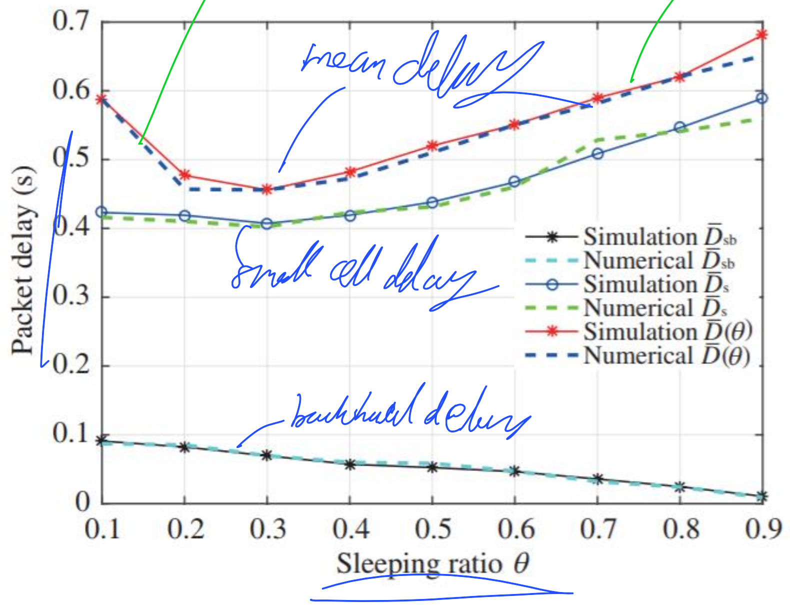


Figure 2 (Color online) Simulation and numerical results for mean packet delay vs. sleeping ratio θ.

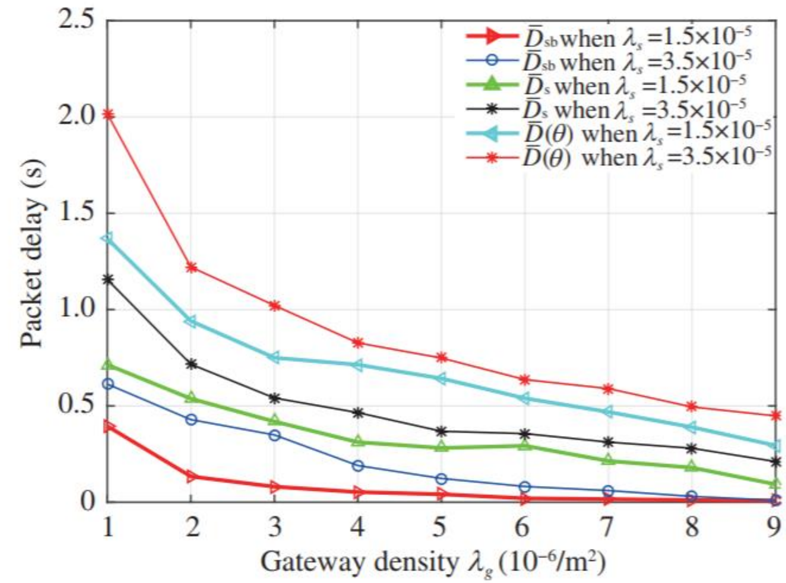


Figure 3 (Color online) Numerical results for mean packet delay vs. gateway density λ_g.

Results and conclusion

System energy consumption

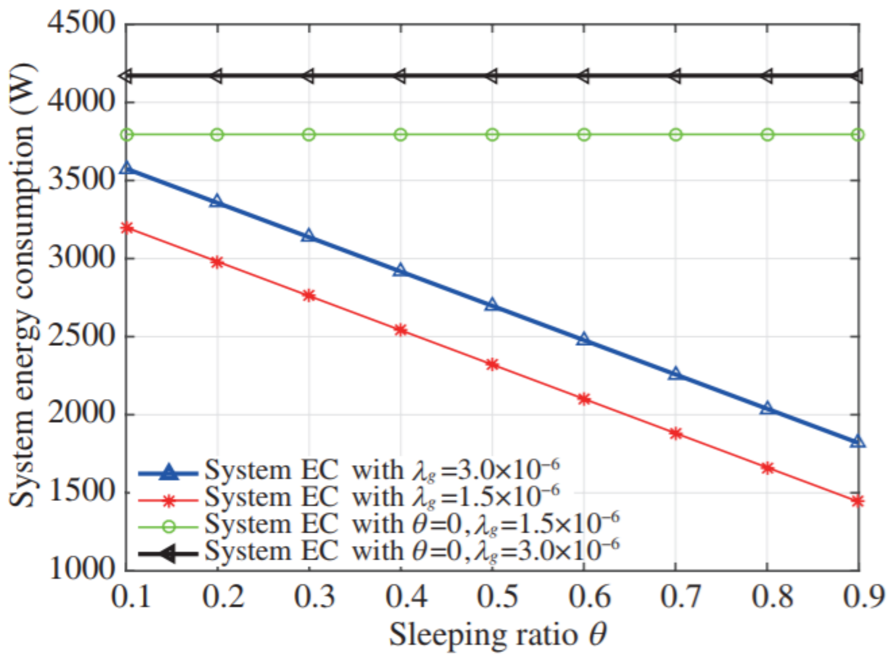


Figure 4 (Color online) Numerical results for system energy consumption vs. sleeping ratio θ.

Results and conclusion

Energy delay tradeoff

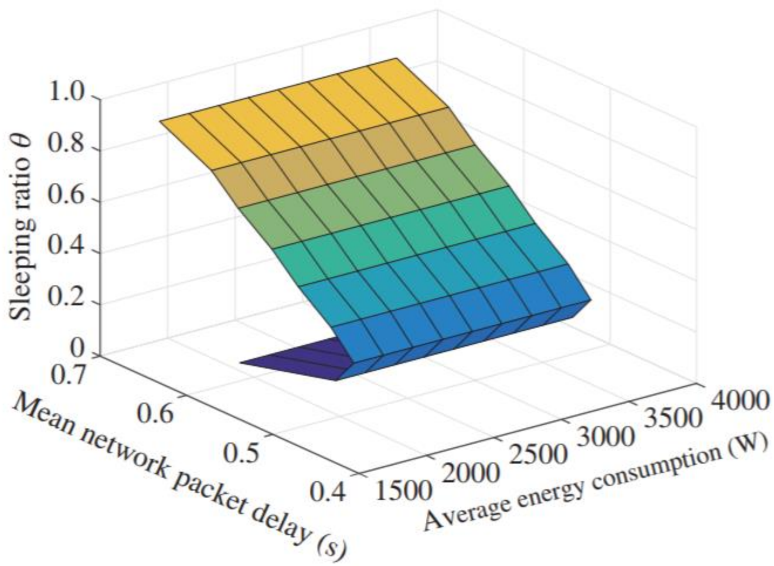


Figure 5 (Color online) Energy consumption vs. mean network packet delay for different θ.

weight

$$F(\theta) = \bar{P}(\theta) + \omega \bar{D}(\theta),$$

delay에 대한 weight.

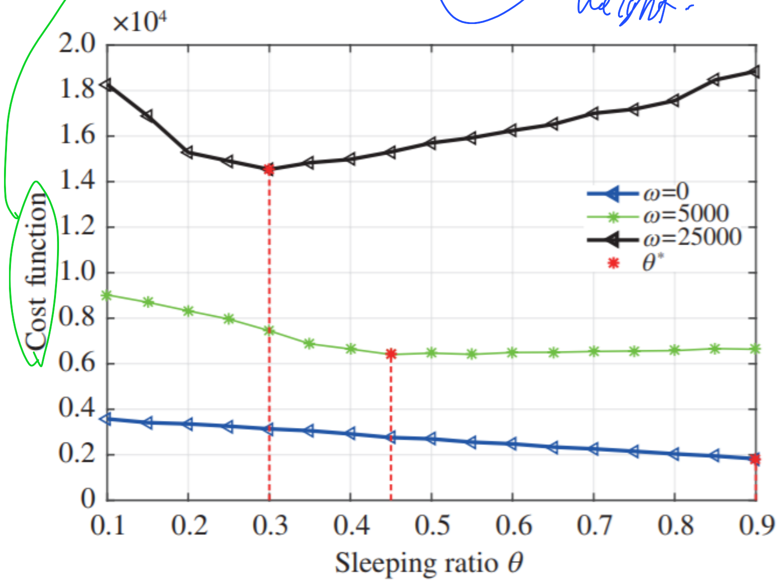


Figure 6 (Color online) Numerical results for cost function of EDT problem vs. BS sleeping ratio θ.

Results and conclusion

Energy delay tradeoff

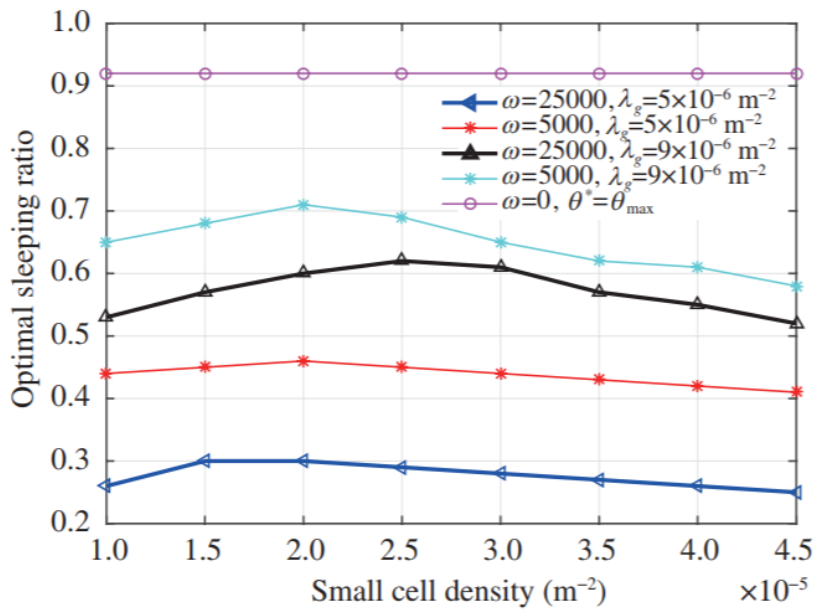


Figure 7 (Color online) Optimal sleeping ratio vs. small cell density for different weighting factor.

Results and conclusion

Energy delay tradeoff

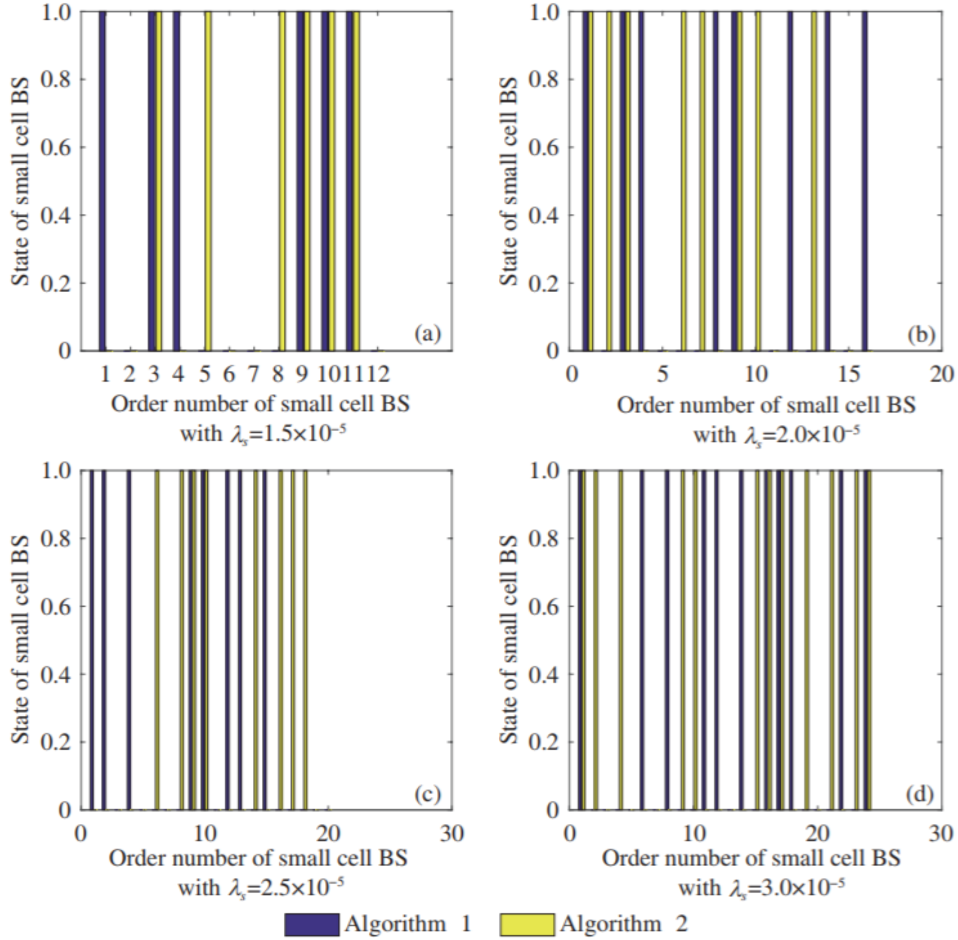


Figure 8 (Color online) Optimal state set of small cells for different small cell density. (a) $\lambda_s = 1.5 \times 10^{-5}$; (b) $\lambda_s = 2.0 \times 10^{-5}$; (c) $\lambda_s = 2.5 \times 10^{-5}$; (d) $\lambda_s = 3.0 \times 10^{-5}$.

Results and conclusion

System performance of proposed sleeping strategy

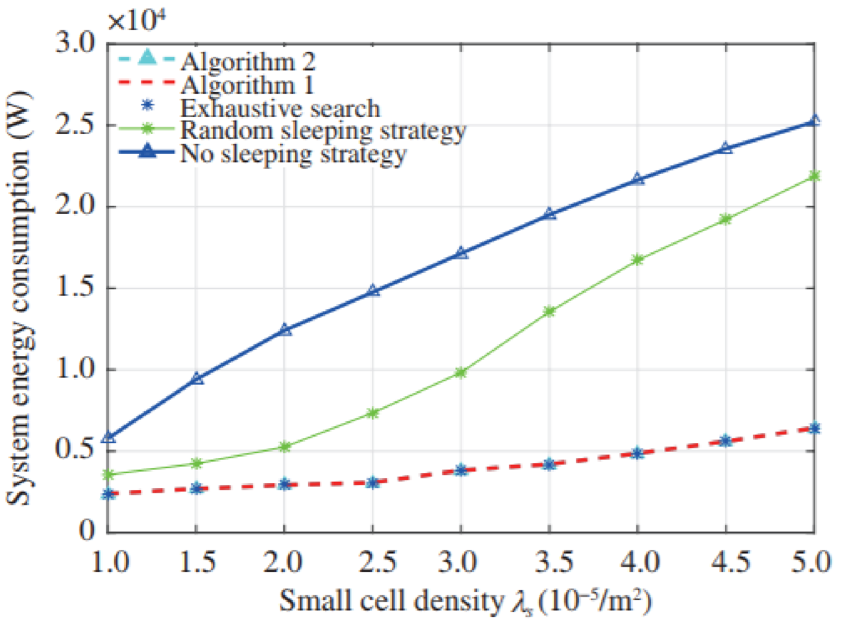
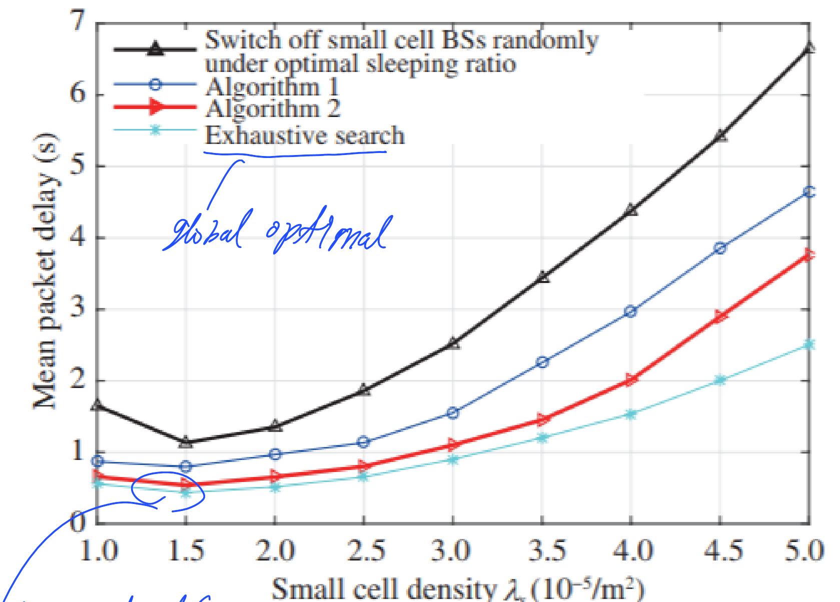


Figure 9 (Color online) System energy consumption vs. λ_s with θ^* for different sleeping schemes.



local optimal (Algorithm 1, 2)가 global optimal 일수는 없어 보였고 에서.

Figure 10 (Color online) Mean delay vs. small cell density with the optimal sleeping ratio for different sleeping schemes.

-> Proposed two algorithms are good!!

Results and conclusion

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Any Questions?

THANK YOU

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