



# Backscatter-Aided Hybrid Data Offloading for Wireless Powered Edge Sensor Networks

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Revolutionizing Communications



# Outline

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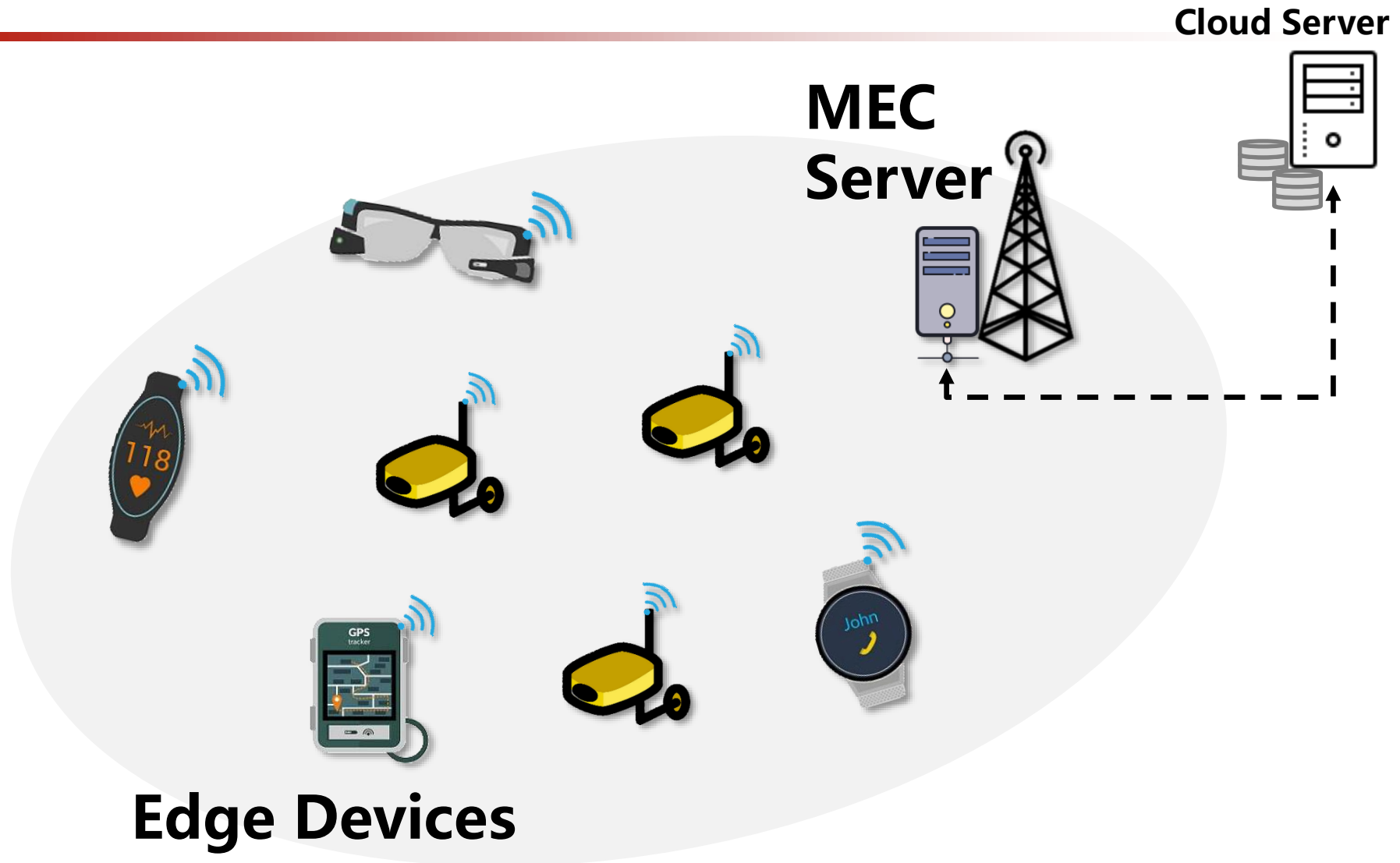
- **Introduction**
- **System Model**
- **Energy Minimization for Hybrid Data Offloading**
- **Numerical Results**

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# Introduction

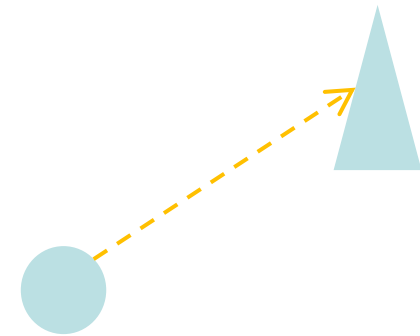


# Introduction

## ■ Communication models in the edge sensor networks

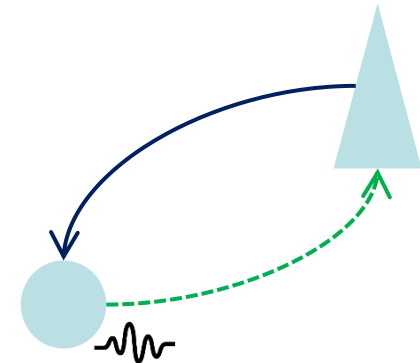
### ◆ Active Transmission

- Relative **high** transmit rate
- **High** energy consumption



### ◆ Passive Transmission

- Relative **low** transmit rate
- **Negligible** energy consumption

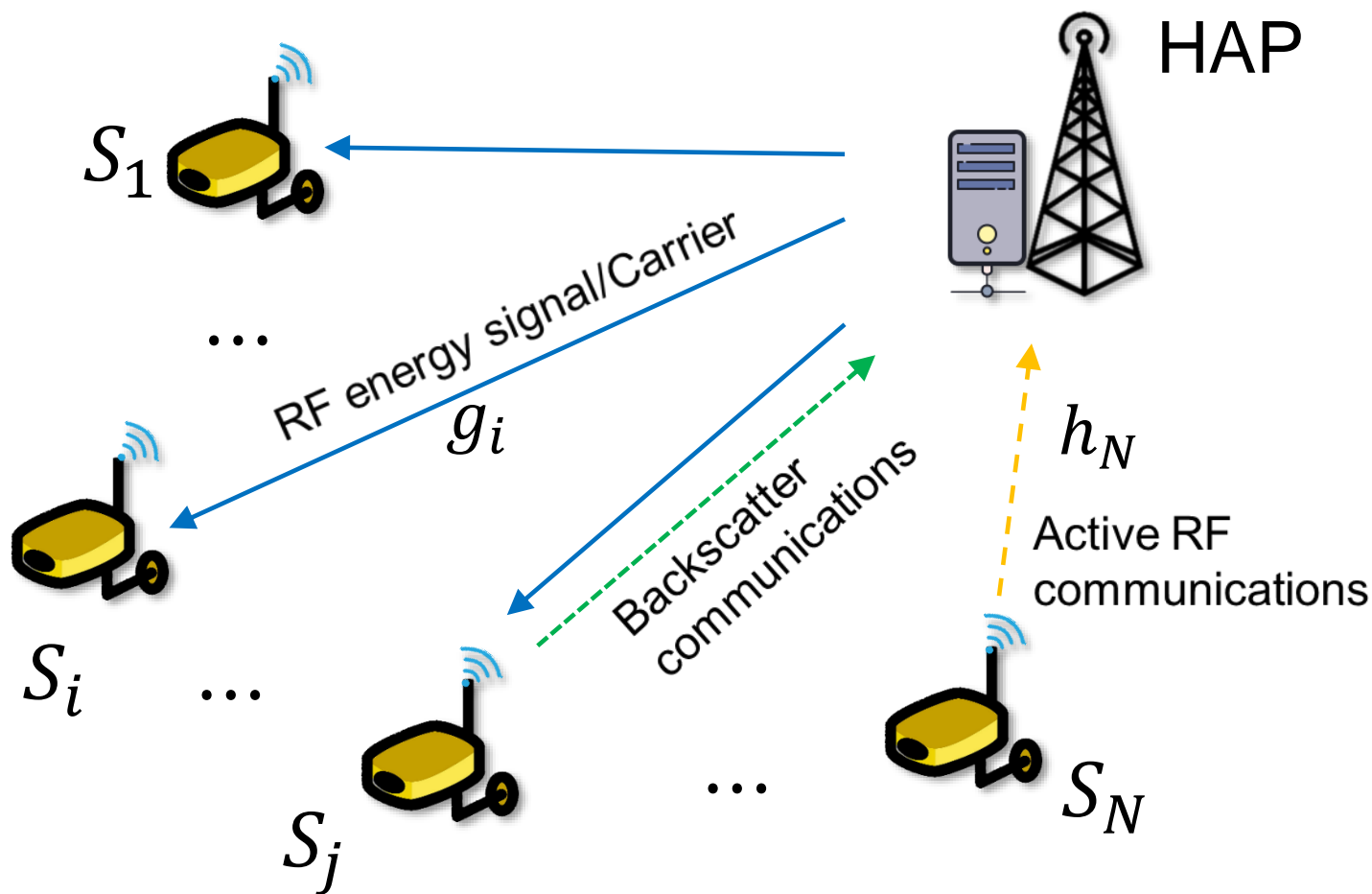


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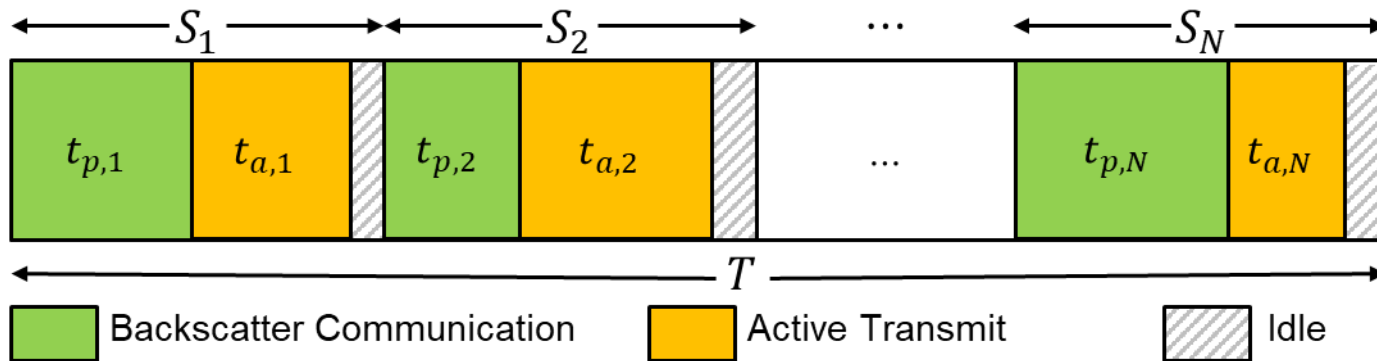
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# System Model



# System Model

## ■ Time Allocation



- ◆ Each sensor is allocated with fixed slot, say  $T/N$
- ◆ Each sensor operate in *passive* and then *active* mode
- ◆ Each sensor harvests energy when others in *passive* mode



# System Model

## ■ Signal Model

### ◆ Active communications

$$r_{a,i} = B \log_2 \left( 1 + \frac{p_{a,i} |h_i|^2}{\sigma^2} \right)$$

$$\begin{aligned} \Leftrightarrow p_{a,i} &= \beta(r_{a,i}) \\ &\triangleq (2^{r_{a,i}/B} - 1) \sigma^2 / |h_i|^2 \end{aligned}$$

Power  
Consumption

### ◆ Passive communication

$$r_{p,i} = r_p \quad \text{Constant}$$

**NOTE:**  $r_{a,i} > r_{p,i}$  holds true in general.

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# Energy Minimization for Hybrid Data Offloading

$$\min_{t_a, t_p} \sum_{i \in \mathcal{N}} p_0 t_{p,i}$$

Energy minimization at HAP

$$\text{s. t. } t_{a,i} + t_{p,i} \leq T/N$$

Slot limitation

$$l_{a,i} + l_{p,i} \geq L_i$$

Task fulfillment

$$t_{a,i} \tilde{\beta} \left( \frac{l_{a,i}}{t_{a,i}} \right) \leq \eta \sum_{j \in \mathcal{N}_i} p_0 g_i^2 t_{p,j}$$

Energy constraint

$$t_{a,i} \geq 0, t_{p,i} \geq 0, l_{a,i} \geq 0$$

Physical constraint

$\tilde{\beta}(r_{a,i}) = \beta(r_{a,i}) + p_{c,i}$  denotes the energy consumption of sensor in active mode

$\eta$ : energy harvesting coefficient,  $\mathcal{N}_i = \mathcal{N} \setminus \{i\}$

$L_i$ : total bits to offload of sensor  $i$ ,  $l_{a,i}$  and  $l_{p,i}$ : bits offloaded via active and passive mode, respectively

# Energy Minimization for Hybrid Data Offloading

$$\min_{t_a, t_p} \sum_{i \in \mathcal{N}} p_0 t_{p,i}$$

$$\text{s. t. } t_{a,i} + t_{p,i} \leq T/N$$

$$l_{a,i} + l_{p,i} \geq L_i$$

$$t_{a,i} \tilde{\beta} \left( \frac{l_{a,i}}{t_{a,i}} \right) \leq E_i$$

$$t_{a,i} \geq 0, t_{p,i} \geq 0, l_{a,i} \geq 0$$

- Distributed reformulation

*Sensor  $i$  is aware of its energy supply, denote by  $E_i$*

> This motivates us to optimize sensors' offloading scheme in a *distributed* manner.

# Energy Minimization for Hybrid Data Offloading

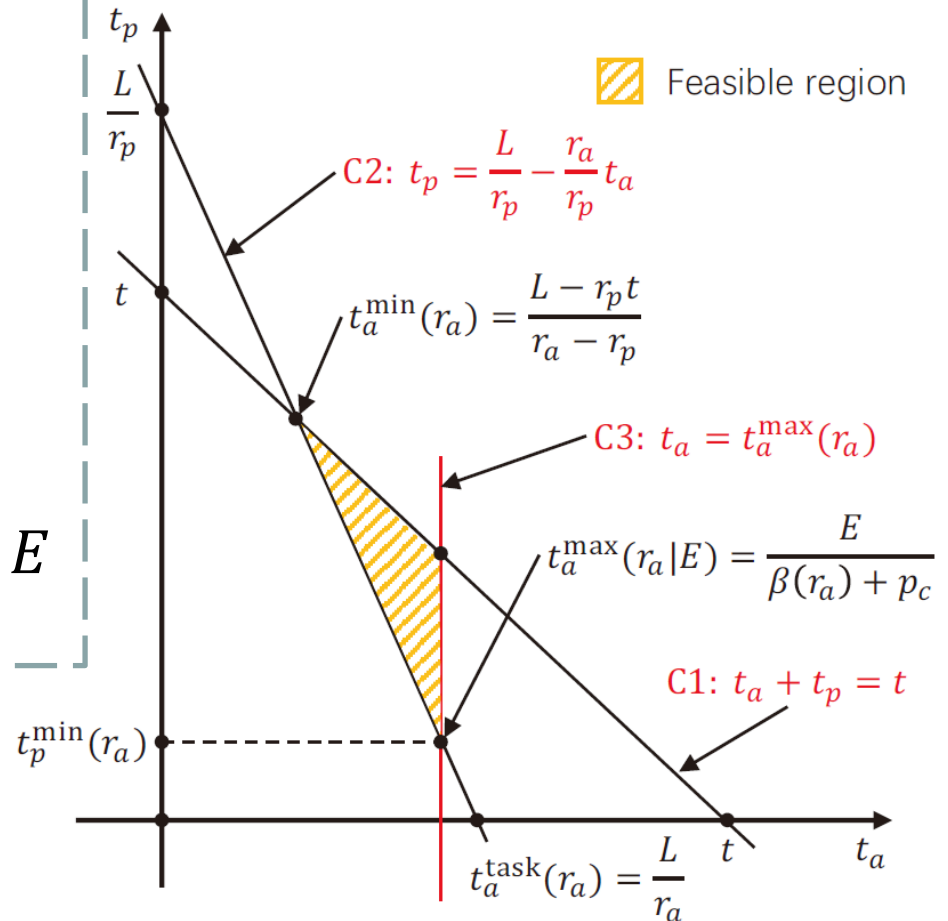
$$\min_{t_a, t_p, r_a} t_p$$

$$\text{s. t. (C1)} \quad t_a + t_p \leq t$$

$$\text{(C2)} \quad t_a r_a + t_p r_p \geq L$$

$$\text{(C3)} \quad t_a \beta(r_a) + p_c t_a \leq E$$

*Closed-form solution can be obtained for each sensor, thus achieves  $\mathcal{O}(1)$  complexity*



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# Numerical Results

## ■ Parameter Settings

HAP's transmit power:  $p_t = 100$  mW

Frame length:  $T = 10$

Sensor workload:  $L = 10$  kbits

Energy harvesting efficiency:  $\eta = 0.8$

Circuit power:  $p_c = 1$   $\mu$ W

Passive data rate:  $r_p = 5$  kbps

Downlink channel gain:  $|g|^2 = -53$  dB

Uplink channel gain:  $|h|^2 = -60$  dB

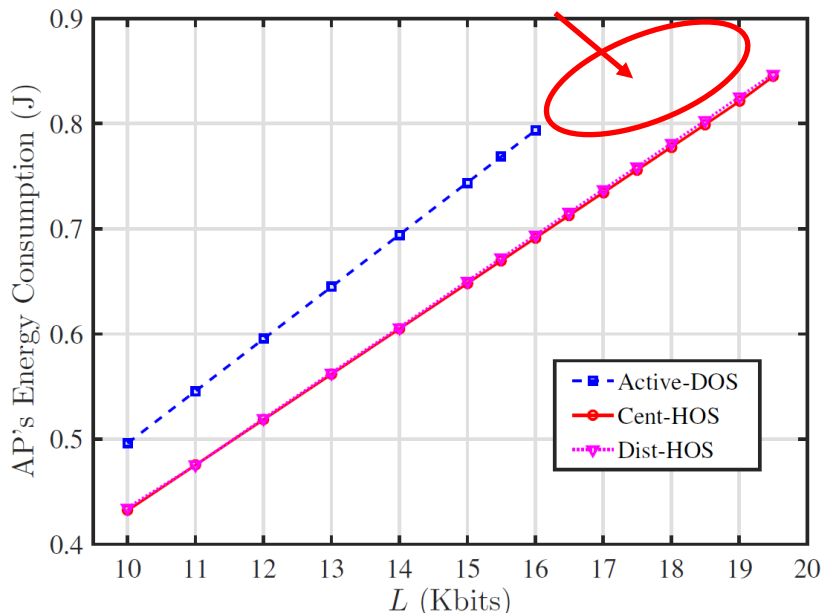
Noise power:  $\sigma^2 = -70$  dBm

Bandwidth:  $B = 400$  kHz

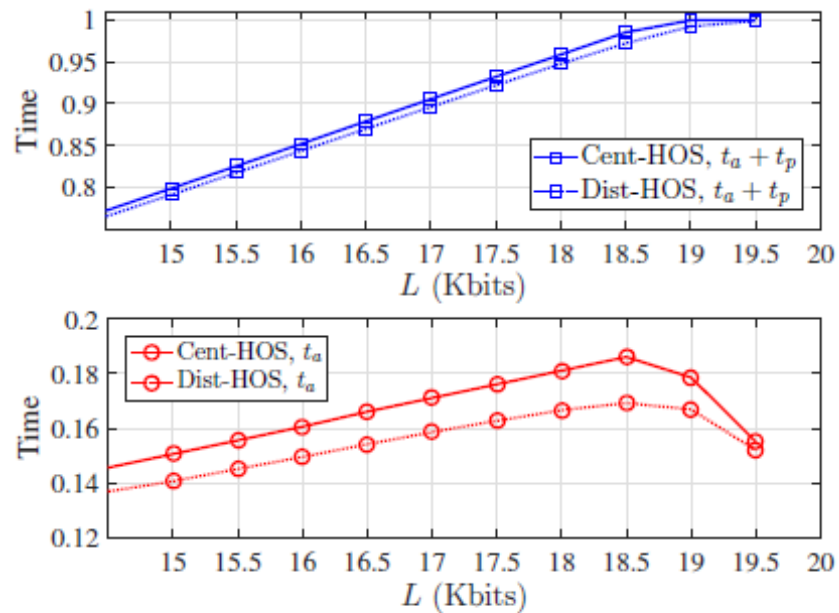
# sensors:  $N = 10$

# Numerical Results

Can not offload the workload in time



(a) The HAP's energy consumption

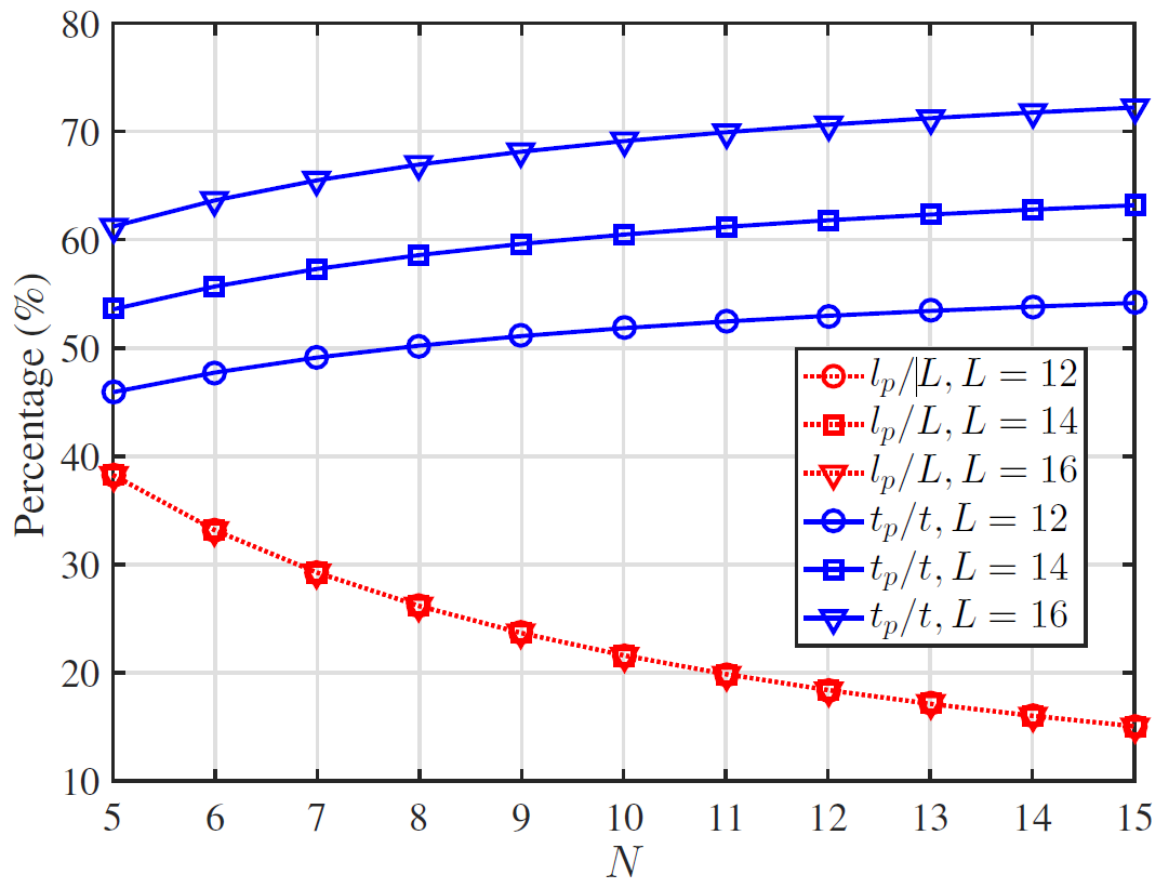


(b) Transmit time allocation

The HAP's energy consumption and transmit time allocation



# Numerical Results



Workload and  
transmit time  
of passive  
data  
offloading

# Q&A

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# Questions & Answers

# Thank you !