IEEE GLOBECOM®

IEEE ComSoc™ IEEE Communications Society

IEEE

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

Yuze Zou, PhD
School of Electronic Information and Communications
Huazhong University of Science and Technology

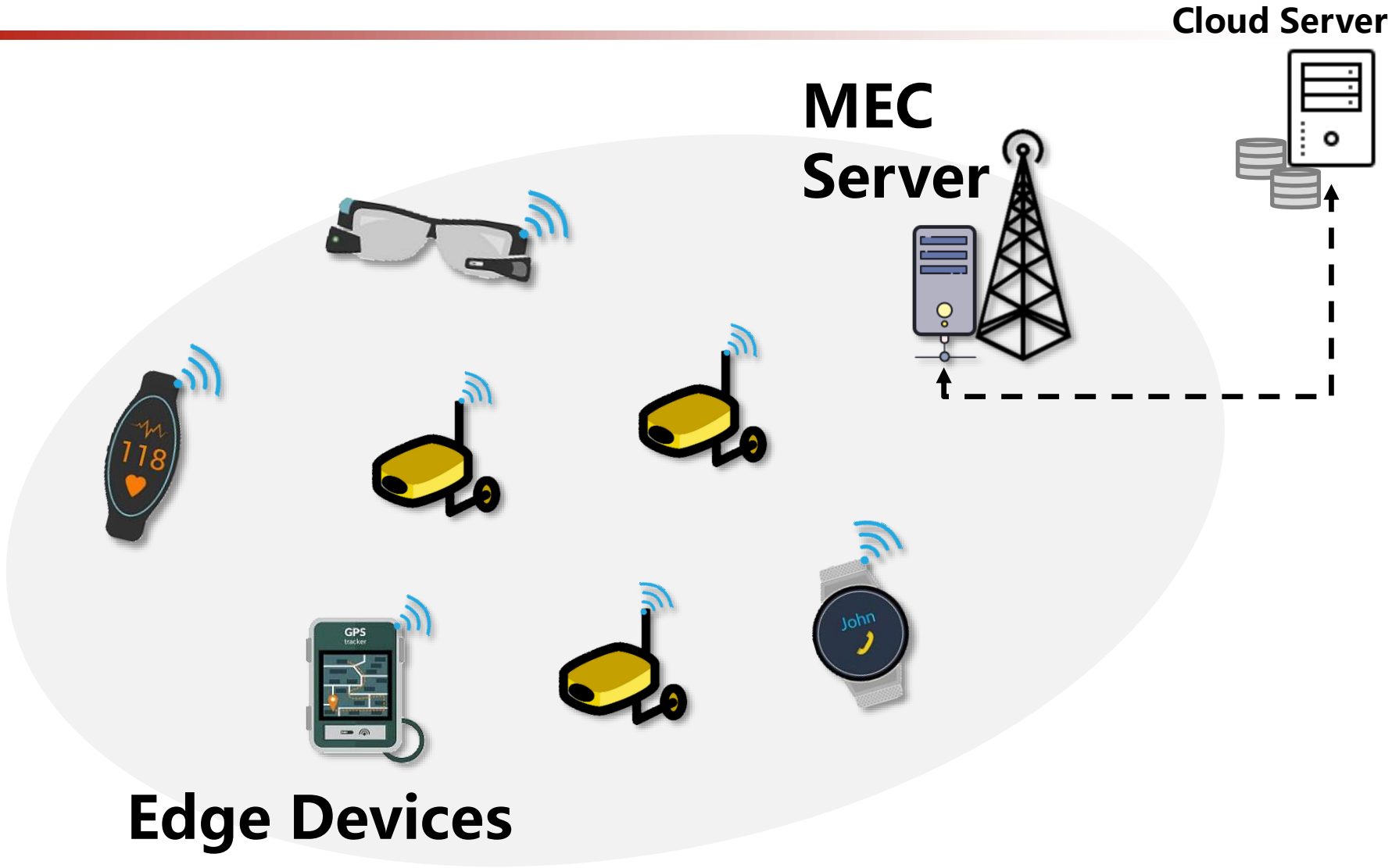
Outline

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

Outline

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

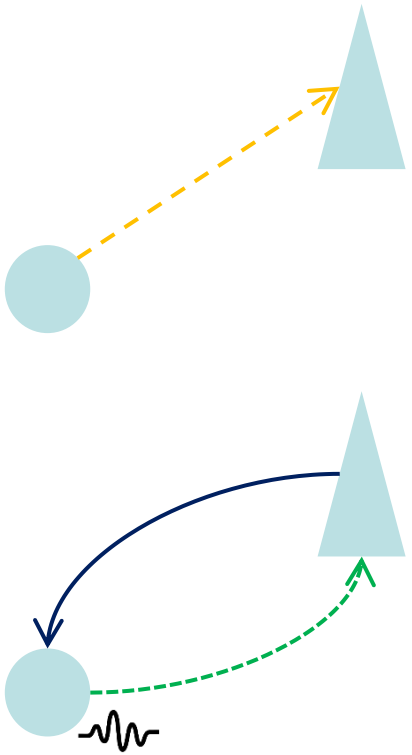
Introduction



Img src: https://www.newgenapps.com/blog/influence-of-iot-on-wearable-technology

Introduction

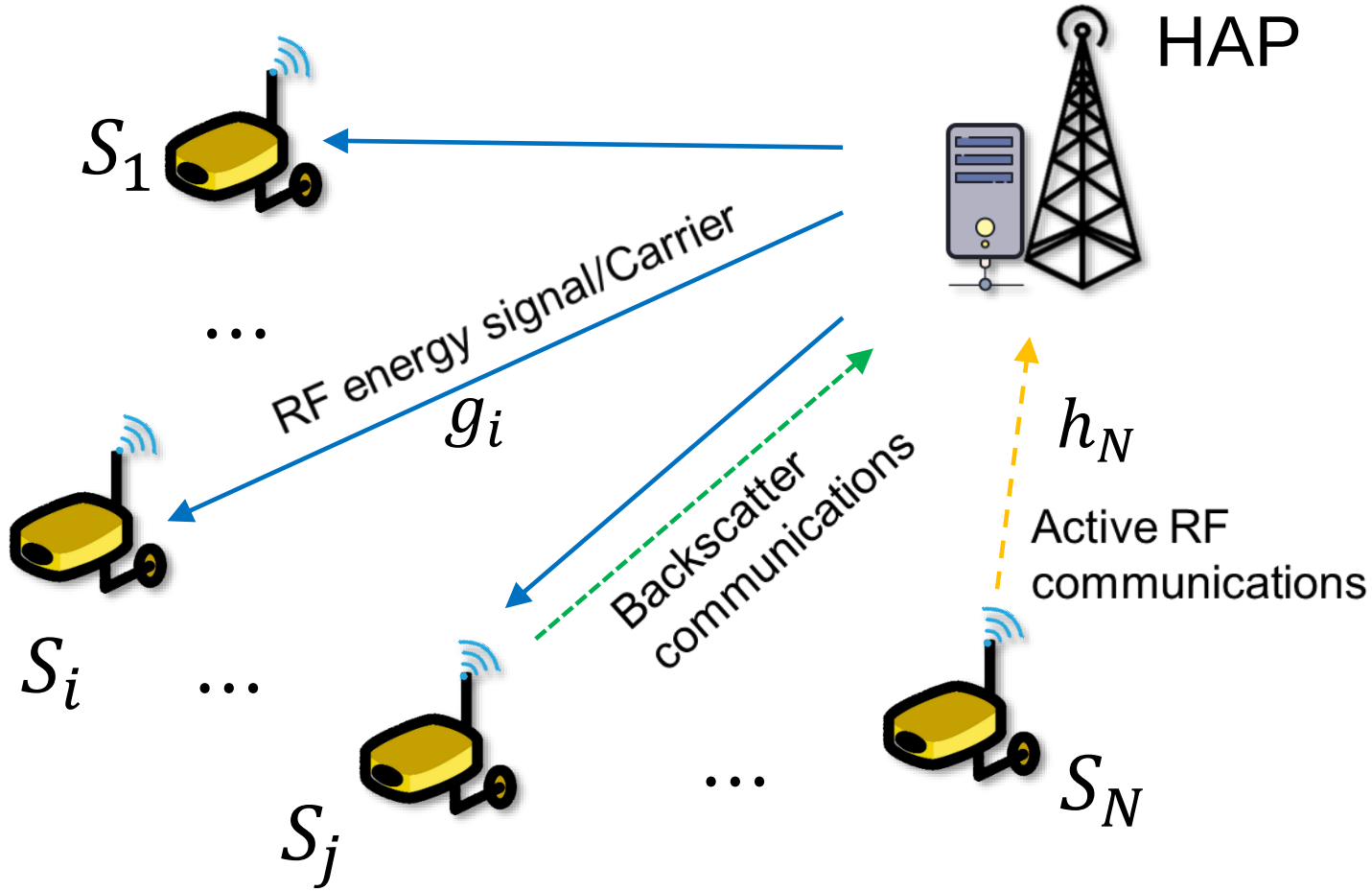
- **Communication models in the edge sensor networks**
  - **Active Transmission**
    - **Relative high transmit rate**
    - **High energy consumption**
  - **Passive Transmission**
    - **Relative low transmit rate**
    - **Negligible energy consumption**



Outline

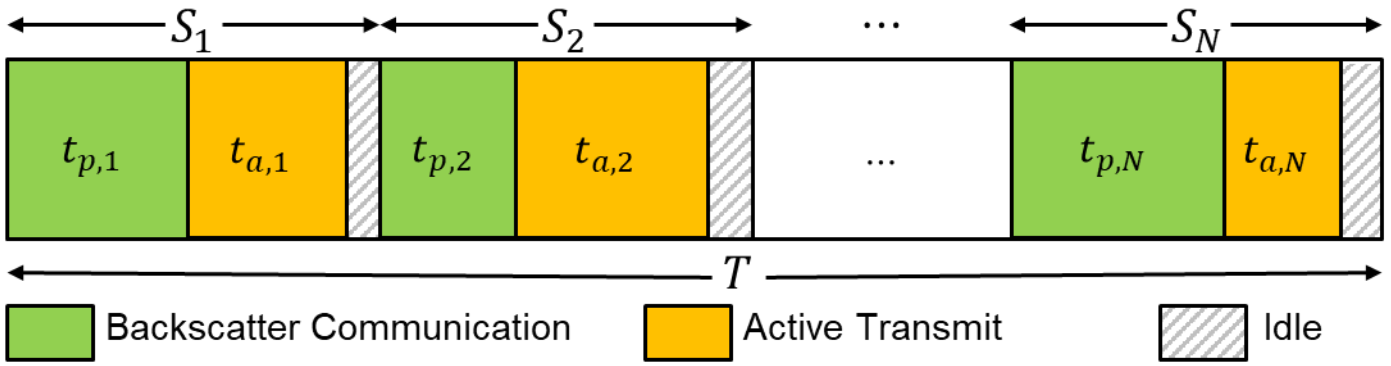
- Introduction
- System Model
- Energy Minimization for Hybrid Data Offloading
- Numerical Results

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

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

$$\Leftrightarrow \quad p_{a,i} = \beta(r_{a,i}) \triangleq \left(2^{r_{a,i}/B} - 1\right)\sigma^2/|h_i|^2$$

Power Consumption

  - Passive communication

$$r_{p,i} = r_p$$

Constant

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

Outline

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

IEEE GLOBECOM

Energy Minimization for Hybrid Data Offloading

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

Energy minimization at HAP

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

Slot limitation

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

Task fulfillment

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

Energy constraint

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

Physical constraint

$\tilde{\beta}(r_{a,i}) = \beta(r_{a,i}) + p_{c,i}$ denotes the energy consumption of sensor in active mode
η: energy harvesting coefficient, $\mathcal{N}_i = \mathcal{N} \setminus \{i\}$
L_i: total bits to offload of sensor i, $l_{a,i}$ and $l_{b,i}$: bits offloaded via active and passive mode, respectively

Energy Minimization for Hybrid Data Offloading

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

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

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

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

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

- 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.

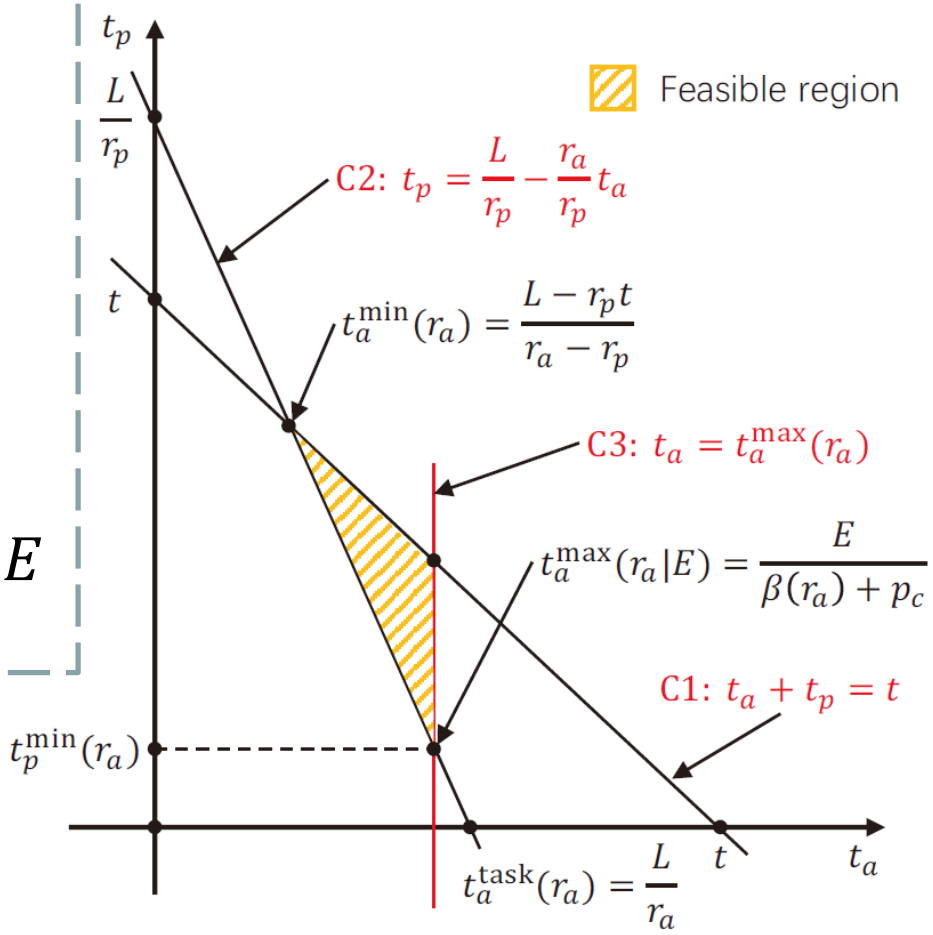
Energy Minimization for Hybrid Data Offloading

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

$$\text{s.t. } (\text{C1})\; t_a + t_p \le t$$

$$(\text{C2})\; t_a r_a + t_p r_p \ge L$$

$$(\text{C3})\; t_a \beta(r_a) + p_c t_a \le E$$



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

Outline

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

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: $p_c = 1$ μW

Passive data rate: $r_p = 5$ kbps

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

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

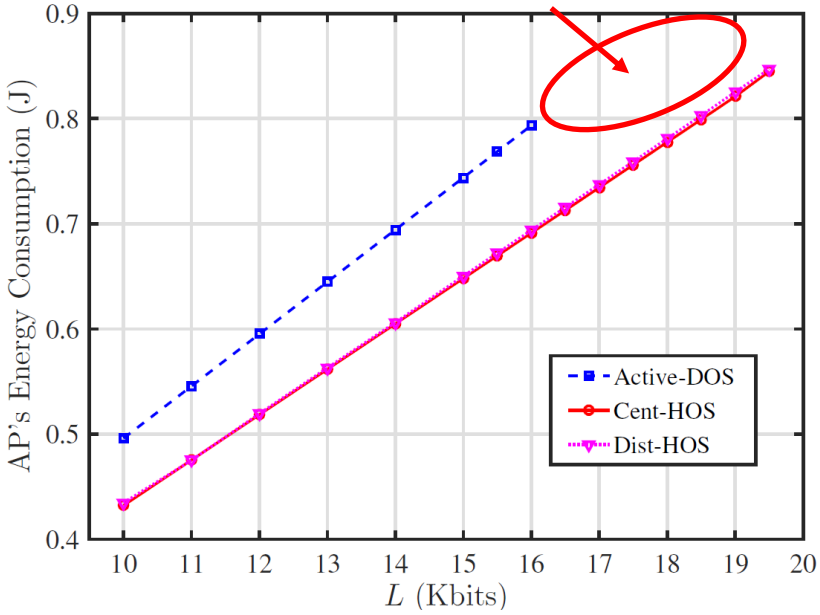
Noise power: $\sigma^2 = -70$ dBm

Bandwidth: $B = 400$ kHz

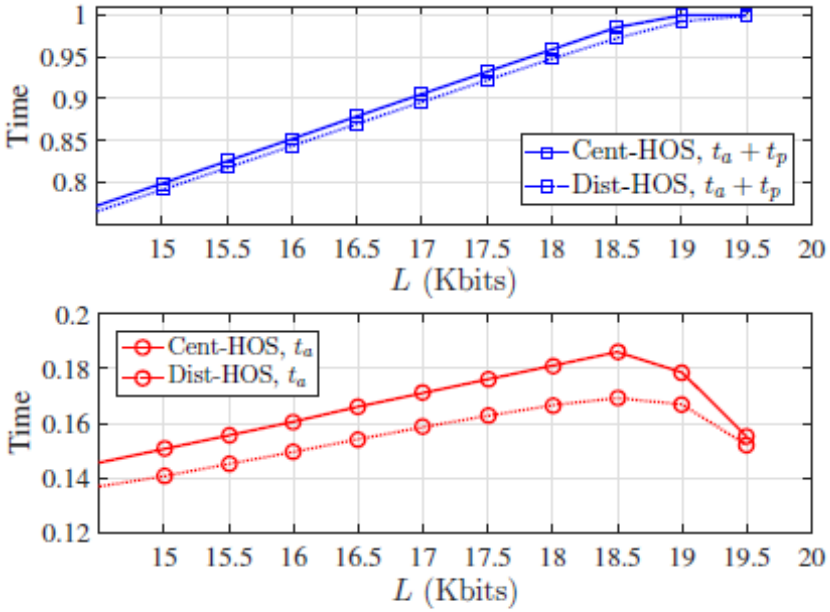
sensors: $N = 10$

Numerical Results

Can not offload the workload in time



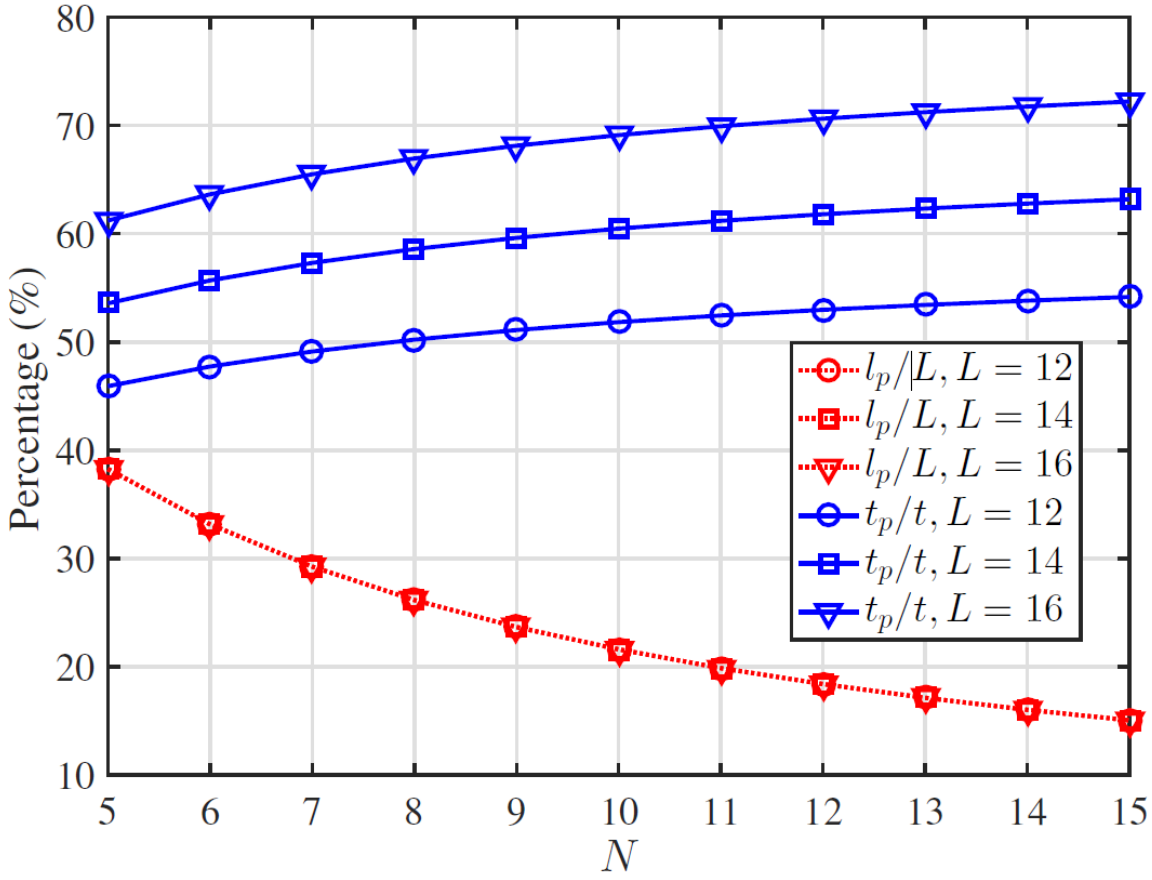
(a) The HAP's energy consumption



(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

Questions & Answers

Thank you !