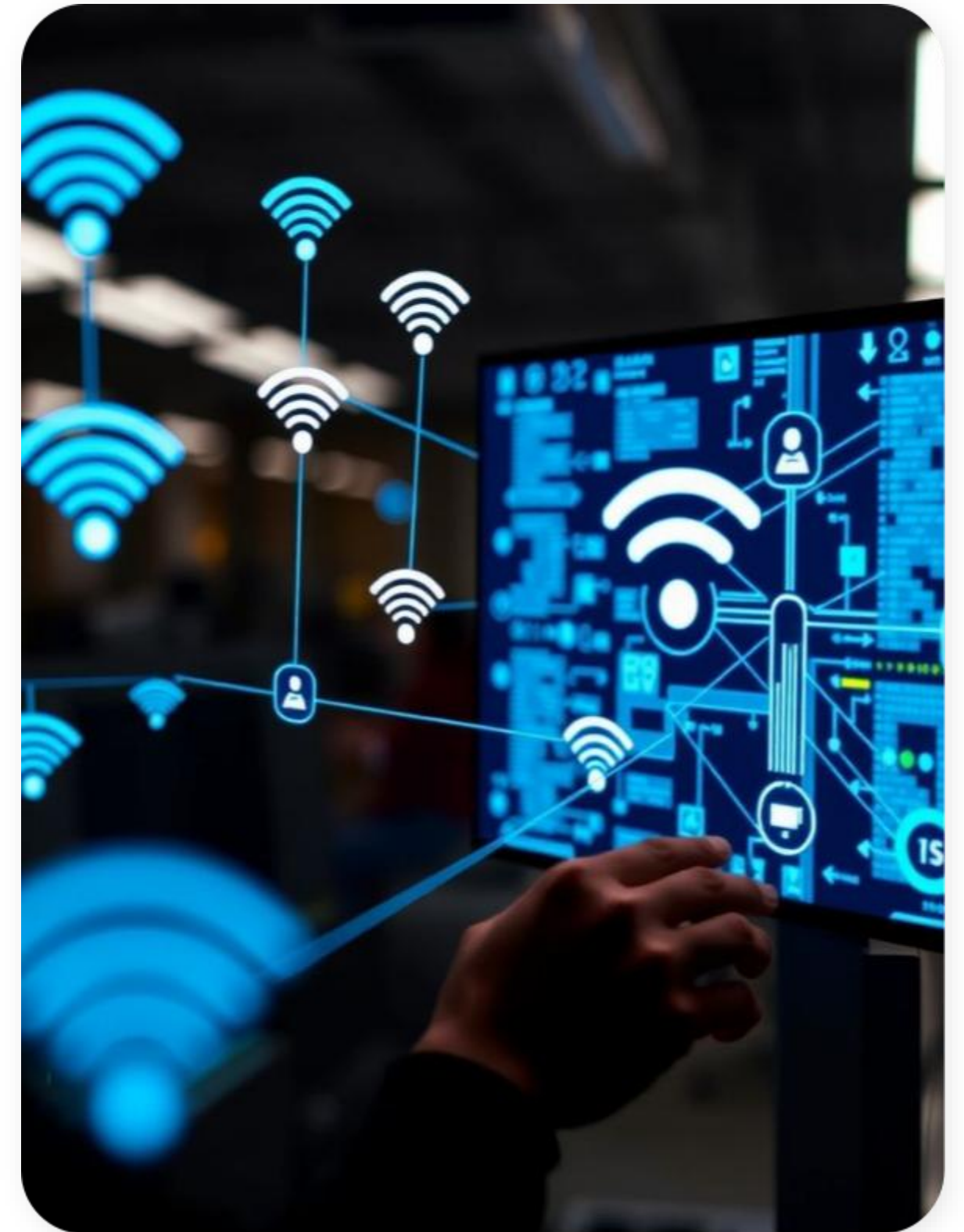


A Group-Based Access Coordination Scheme for Low-Latency and High-Throughput IoT over IEEE 802.11ah

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Presenter



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Education

- B.S Course in Department of Global business Sungshin University, 2021.03 ~ 2023.02
- B.S. Course in Convergence Security Engineering, Sungshin University, Seoul, Korea, 2023.03 ~
- M.S. Course in Convergence Security Engineering, Sungshin Women's University, Seoul, Korea, 2025.03 ~

R&D Projects

- Attack Surface Analysis and Digital Immunity Technologies for Low Earth Orbit Satellite-Based Internet of Things: Firmware Vulnerability Analysis and Automatic Recovery Technology (MSIT, NRF), 2025.03.01-2028.02.28
- Training Industrial Security Specialist for High-Tech Industry (MOTIE, KIAT), 2024.03.01-2029.02.28
- ICT Innovative Talent 4.0: Next Generation Communication Network and Security (MSIT, IITP), 2022.07.-2026.12.
- R&D on Information Security Core Technologies: Development of anti-sniffing technology for mobile communication and AirGap environments (MSIT, IITP), 20224.06.01-2026.12.31
- Specialized Support Project for Technological Security Operation, 2024.03.01-2024.12.31.

Working Experience

- Sungshin University, Seoul, Korea
- CSE Undergraduate Internship Students (2023.11 ~ 2025.01)
- Teaching Assistant (TA) in Dept. of Convergence Security Engineering, Sungshin Women's University, 2025.03~2025.08
- Research Assistant (RA) in CSE Lab

Research Interest

- IoT Security/Network
- Network Security
- Digital ID



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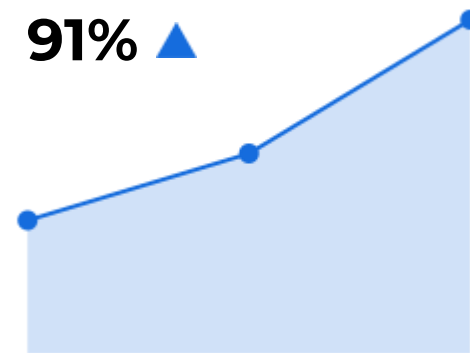
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Conculsion

Background

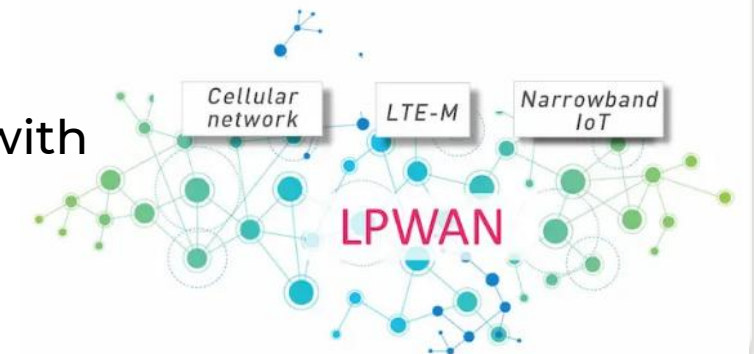
IoT devices increase

- The number of IoT devices is steadily increasing and is expected to grow by 91% from 2025 to 2030.
- Consequently, IoT networks require wide coverage, high throughput, and real-time performance.



LPWAN (Low-Power Wide Area Network)

- Exemplified by LoRa.
- Enables long-range communication with low data rates.



WPAN (Wireless Personal Area Network)

- Represented by ZigBee and BLE (Bluetooth Low Energy).
- Provides short-range connectivity with moderate data transmission speeds

WPAN



Wi-Fi HaLow

- Designed to overcome the limitations of existing IoT communication technologies.
- Integrates several key MAC-layer functions:
 - Fast authentication and association
 - Restricted Access Window (RAW)
 - Traffic Indication Map (TIM) partitioning
 - Target Wake Time (TWT)



Background

RAW scheme pros

- Effective in high-density environments with a large number of STAs.
- Enhances the efficiency of energy-constrained STAs.
- A flexible distributed channel access mechanism applicable under diverse network conditions.

RAW scheme cons

- Latency issues for delay-sensitive traffic.
- Focused mainly on throughput improvement, without considering latency.

Proposed scheme : SRAW-GC

- Utilizes a grouping-based approach to organize traffic and allocate time slots based on group characteristics.
- Prioritizes scheduling for nodes requiring low latency.
- Achieves high throughput by applying the A-MPDU technique.

Related Work



Traffic indication map (TIM) segmentation

- **Partitioning TIM information in the beacon by groups**
→ STAs are active only during their assigned group time, improving energy efficiency.



Target wake time (TWT)

- **Negotiation of active time between STA and AP**
→ Communication occurs only in the reserved slots, while the remaining time is spent in sleep mode, significantly enhancing power efficiency.



Restricted access window (RAW)

- Grouping STAs for channel access within specific time slots**
- Reduces collisions and improves network scalability.

Feature	Ref.	Contribution	Limitation
TIM segmentation	[5]	The proposed network architecture enhances scalability by incorporating control loops and monitoring sensors into the network infrastructure.	It has been demonstrated that if the beacon cycle is not optimized, there will be an increase in throughput and energy consumption.
TWT	[7]	The proposed methodology involves implementing a multifaceted approach, integrating the utilization of RAW and TWT, to enhance network energy efficiency.	It has been demonstrated that there is an increase in latency when using RAW and TWT in conjunction with one another.
RAW	[9]	The proposal entails implementing a RAW mechanism to identify concealed terminals and organize STAs into designated groups.	It has been demonstrated that an increase in network latency is associated with a failure to consider traffic latency requirements.

Proposed scheme

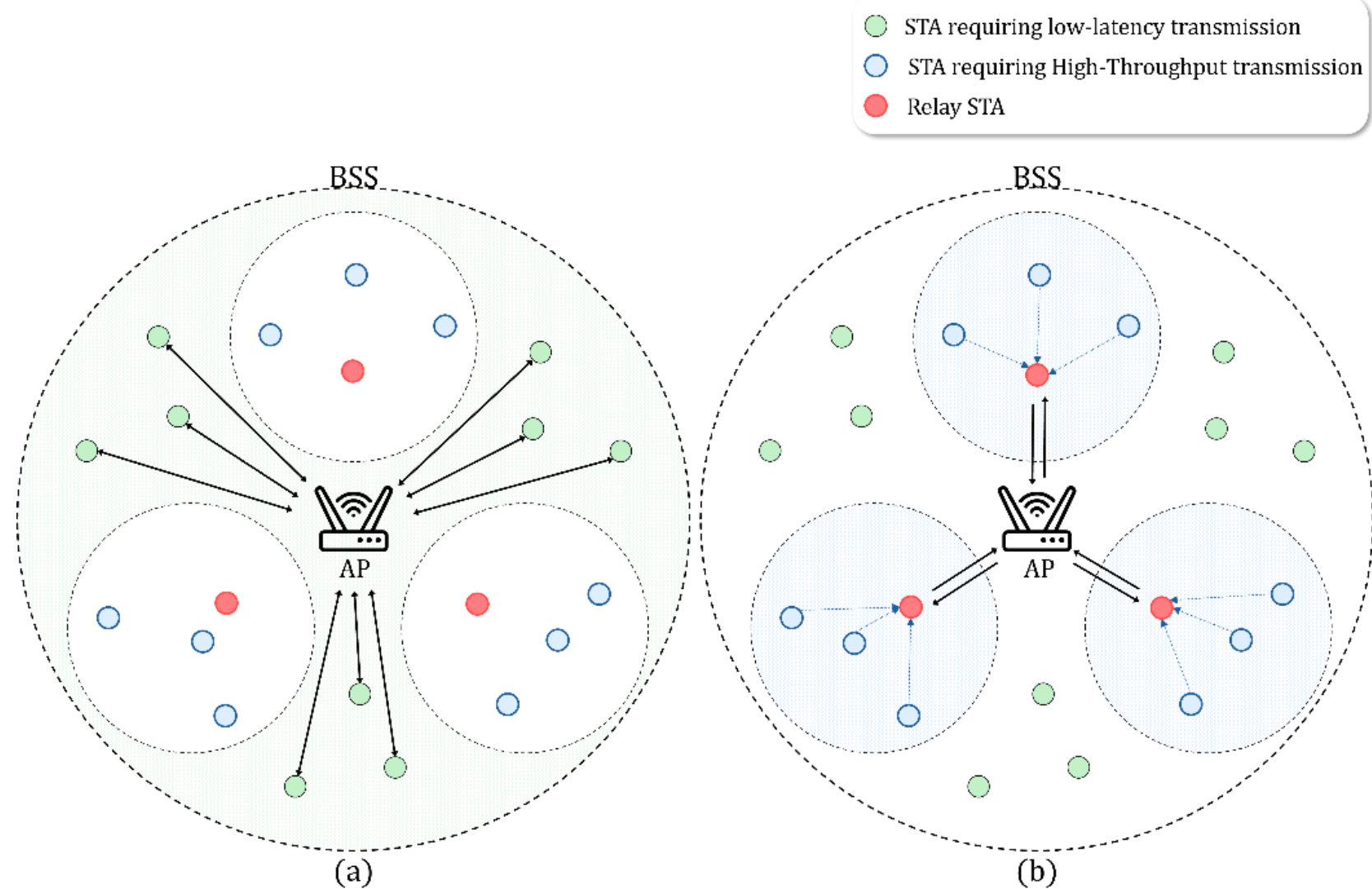


Fig. 1. This is how STAs (stations) that require low latency and STAs that require high bandwidth transmit data to AP (access point). (a) shows how low-latency STA communicates with AP, and (b) shows how high-bandwidth STA communicates with AP.

SRAW-GC

- STA Classification
 - **Low-latency STAs:** Require short delay → Transmit individual MPDUs
 - **High-throughput STAs:** Require high throughput → Use Relay STAs for aggregated A-MPDU transmission
- Relay STA Selection
 - Based on **MCS (Modulation and Coding Scheme) index**
 - Optimal relay determined through channel quality evaluation between AP and STA
- Transmission Method
 - **Low-latency STAs:** Irregular data generation → Immediate transmission is more efficient
 - **High-throughput STAs:** Utilize A-MPDU → Aggregate and batch transmission maximizes throughput
- Low-latency and high-throughput transmissions operate within sub-slots of the RAW slot

Proposed scheme

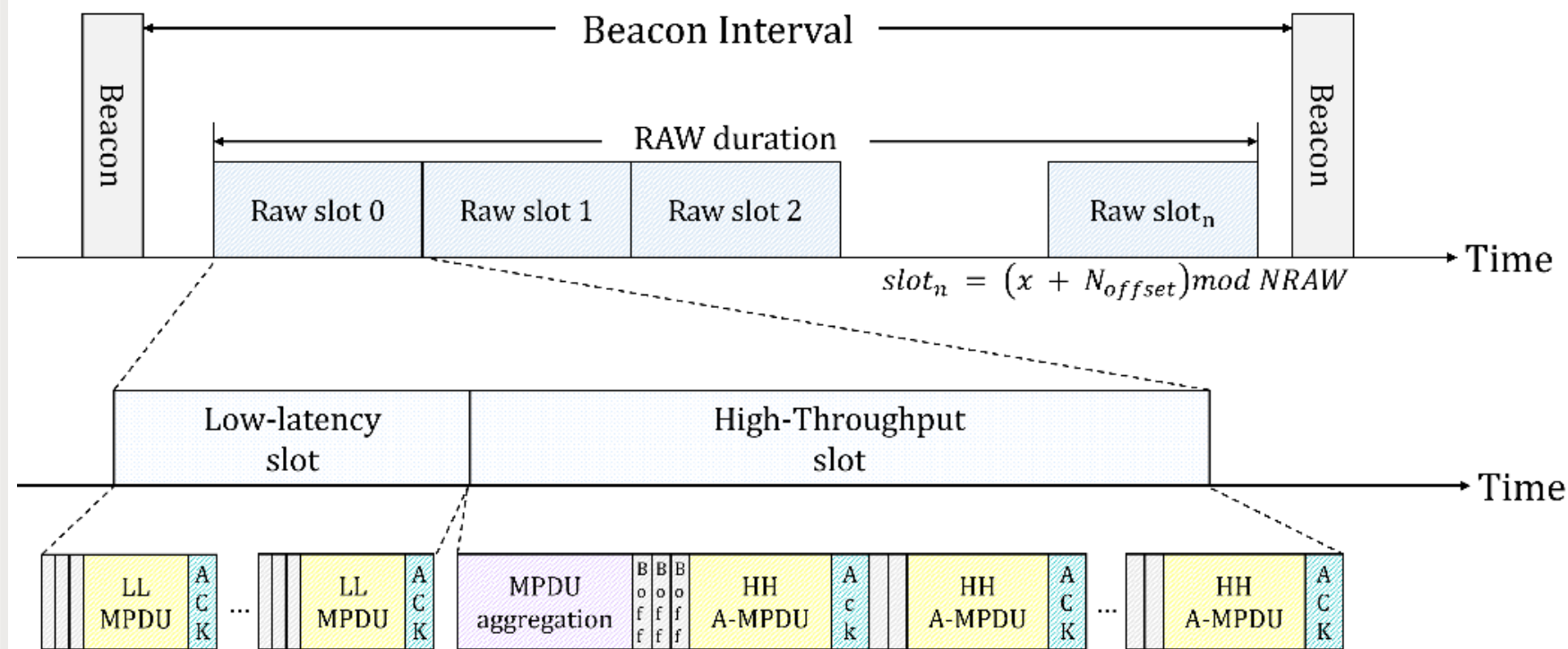


Fig. 2. SRAW-GC technique showing a RAW slot divided into a low-latency sub-slot for individual transmissions and a high-throughput sub-slot for aggregated A-MPDU transmissions

SRAW-GC

- Compatibility with 802.11ah RAW
 - STAs are assigned to RAW slots using Equation (1), based on AID and offset values.
- RAW Slot Structure
 - Low-Latency Sub-Slot:
 - STAs requiring low latency directly compete with the AP to transmit MPDUs.
 - Prioritized access minimizes delays compared to high-throughput STAs
 - High-Throughput Sub-Slot:
 - AP selects relay STAs within the BSS.
 - Relay STAs collect MPDUs from nearby STAs, aggregate them (A-MPDU), and transmit to the AP.
 - Reduced competition and collisions → improved throughput efficiency.

Evaluation

Evaluation Environment



Evaluation setup

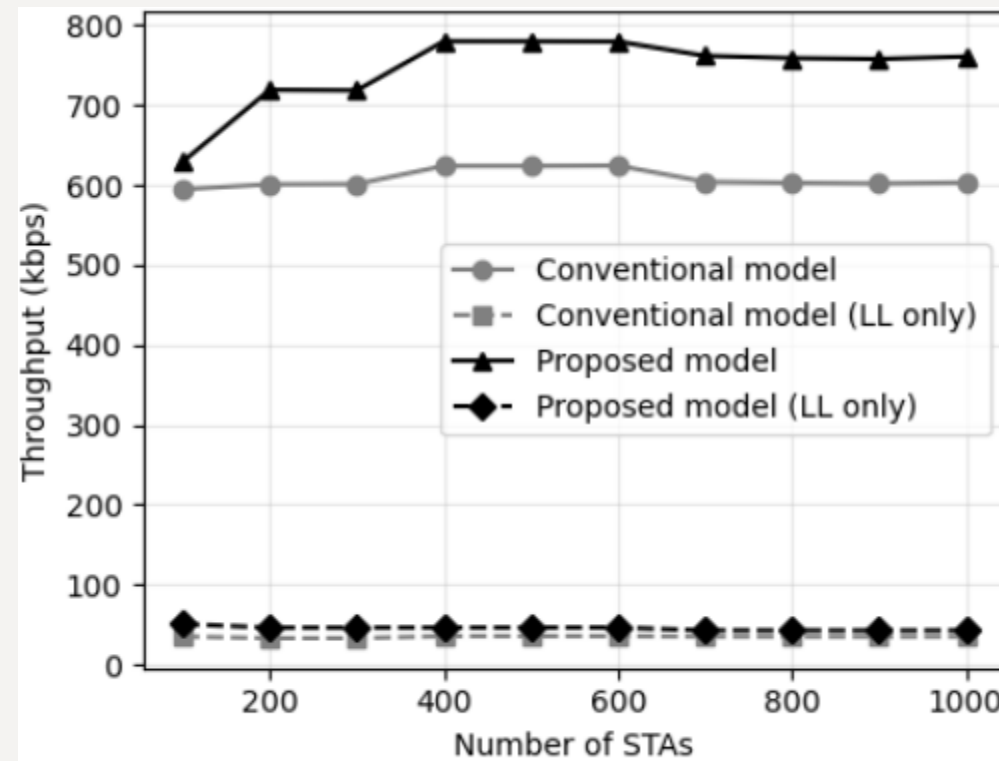
- Conventional model : 802.11ah RAW mechanism
- Simulation environment : one AP and 2,000 STAs within a single BSS
- Scenario
 - The number of STAs
 - The ratio of low-latency STAs to high throughput STAs
 - The collision probability among STAs

Evaluation metrics

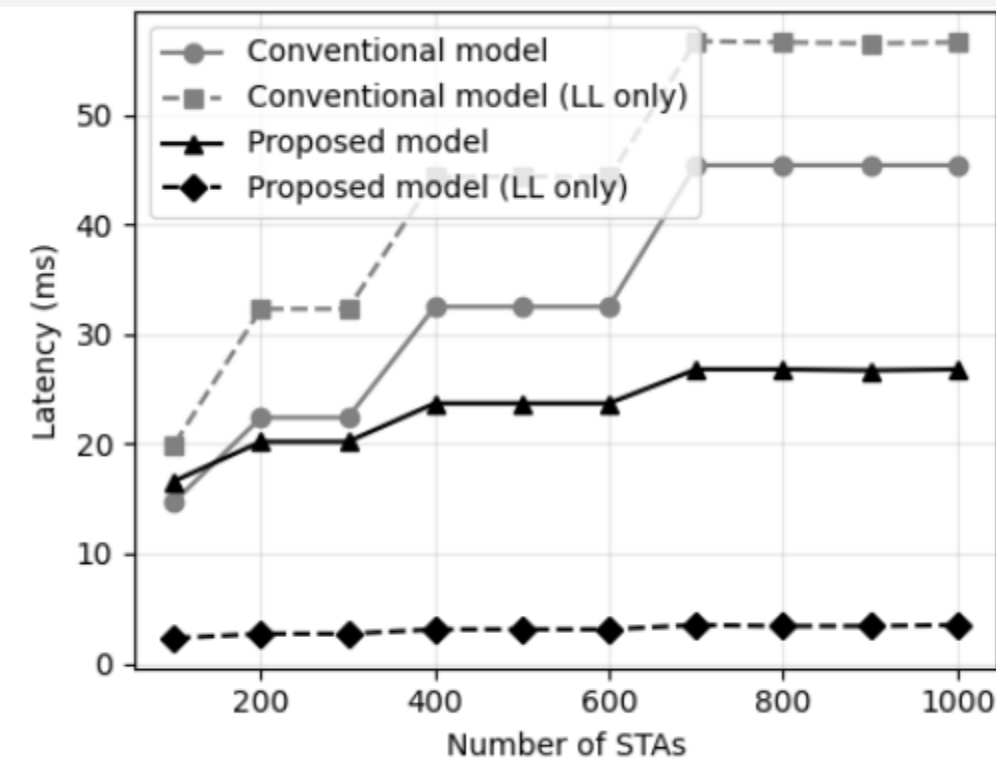
- $Throughput(kbps) = \frac{\sum_{i=1}^n D_i(bytes) \times 8}{T_{RAW}(ms)}$
- $Latency(ms) = T_{Data\ transmission} + (T_{backoff} \times N_{backoff})$
- $E_{total}(J) = \sum_{n=1}^N E_{STA}(n)$
- $E_{STA}(J) = P_{base} \times (T_{active,n}/1000) + P_{idle} \times (T_{idle,n}/1000)$

Evaluation

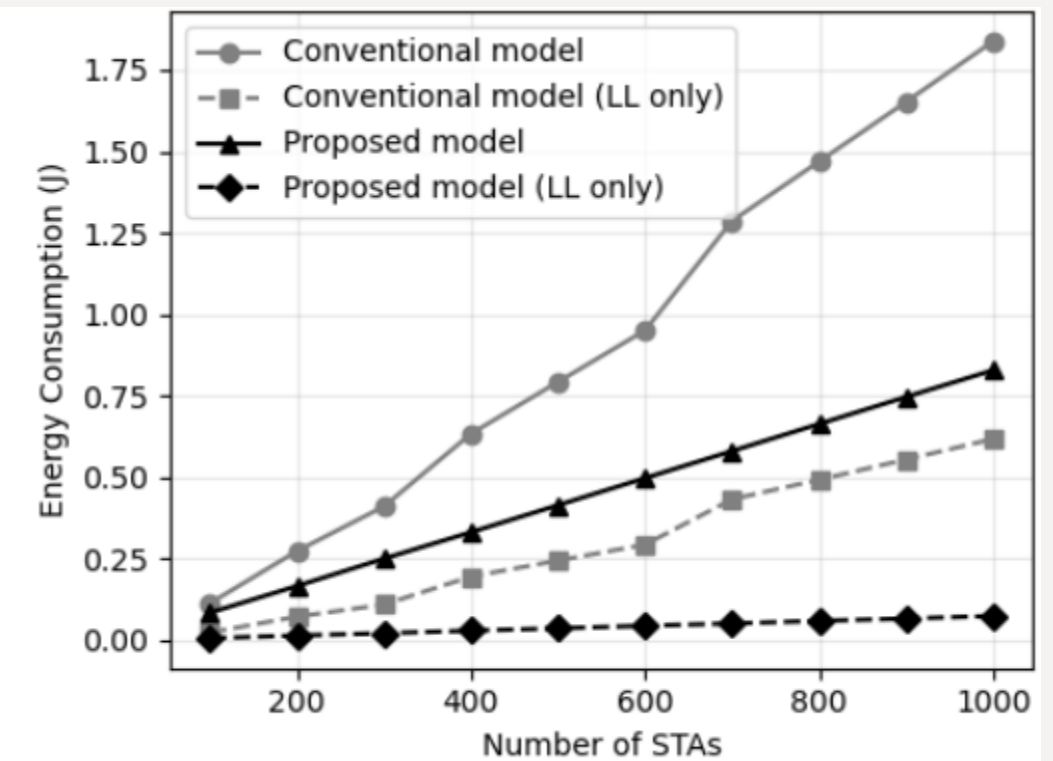
Evaluation Results and Analysis



(a) Throughput



(b) Latency



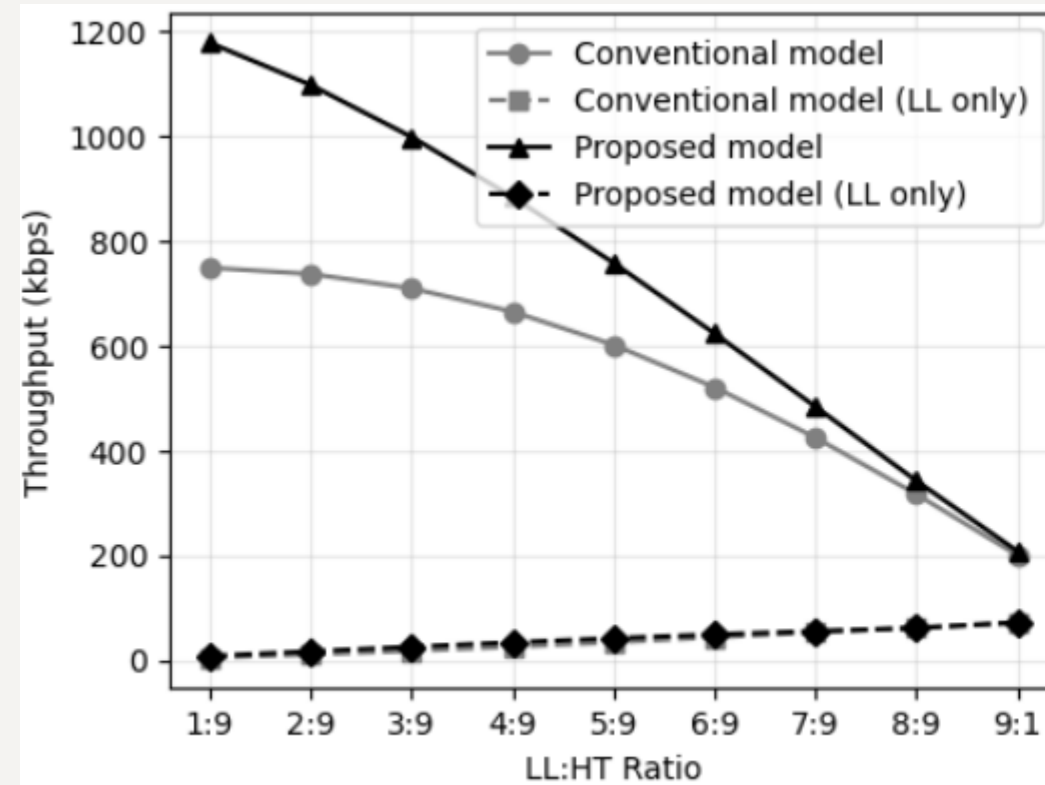
(c) Energy Consumption

Scenario 1. The number of STAs

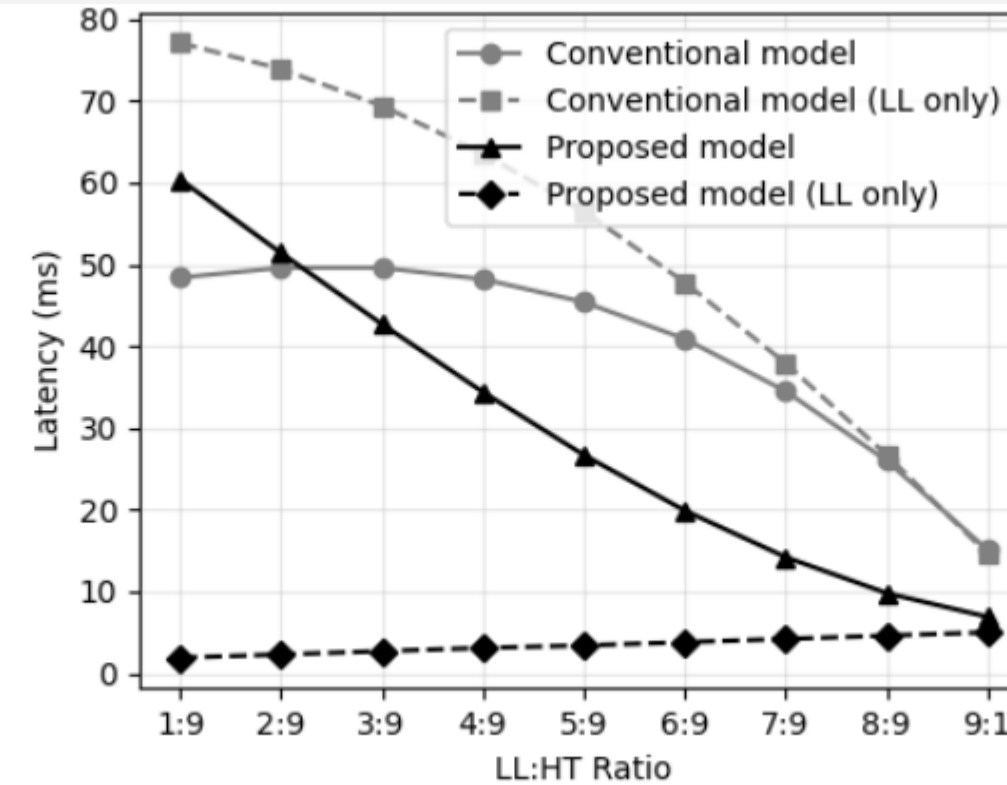
- **Throughput:** Proposed model improves overall throughput (779.7 kbps vs. 624.4 kbps) and achieves 30.3% higher throughput for low-latency STAs.
- **Latency:** Proposed model reduces average latency by up to 41.1% compared to the conventional model as STA count increases.
- **Energy Consumption:** Proposed model achieves up to 51.5% lower energy consumption through relay-based aggregation and separate contention management.

Evaluation

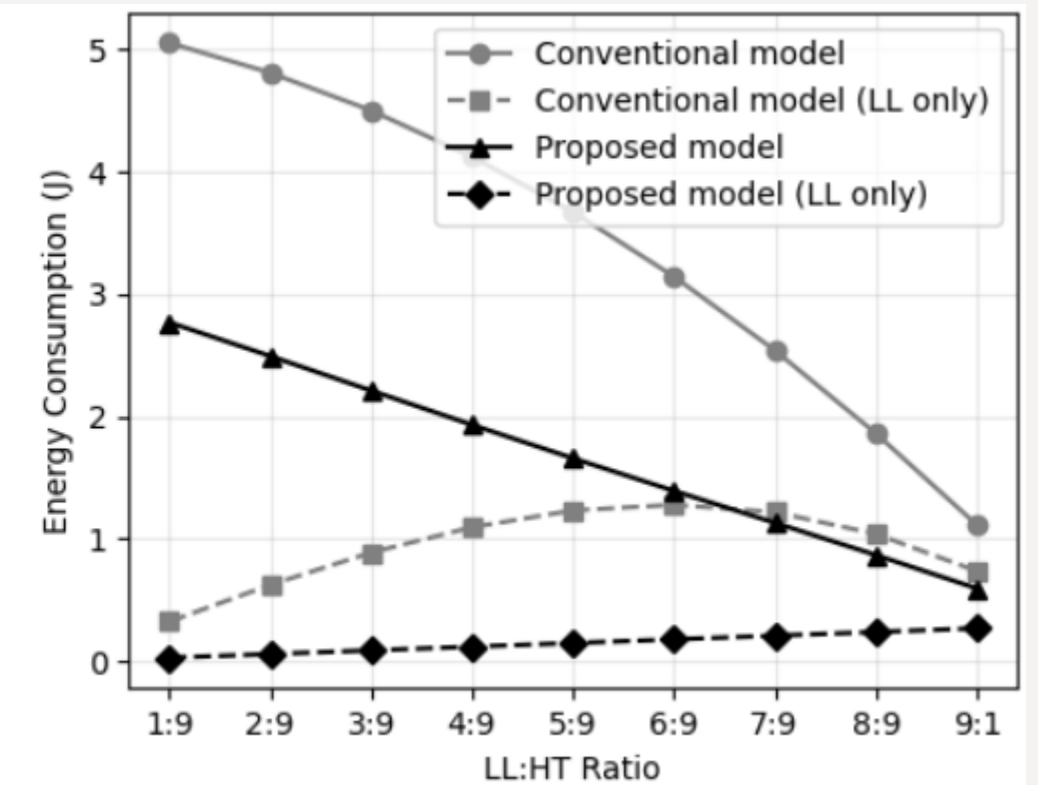
Evaluation Results and Analysis



(a) Throughput



(b) Latency



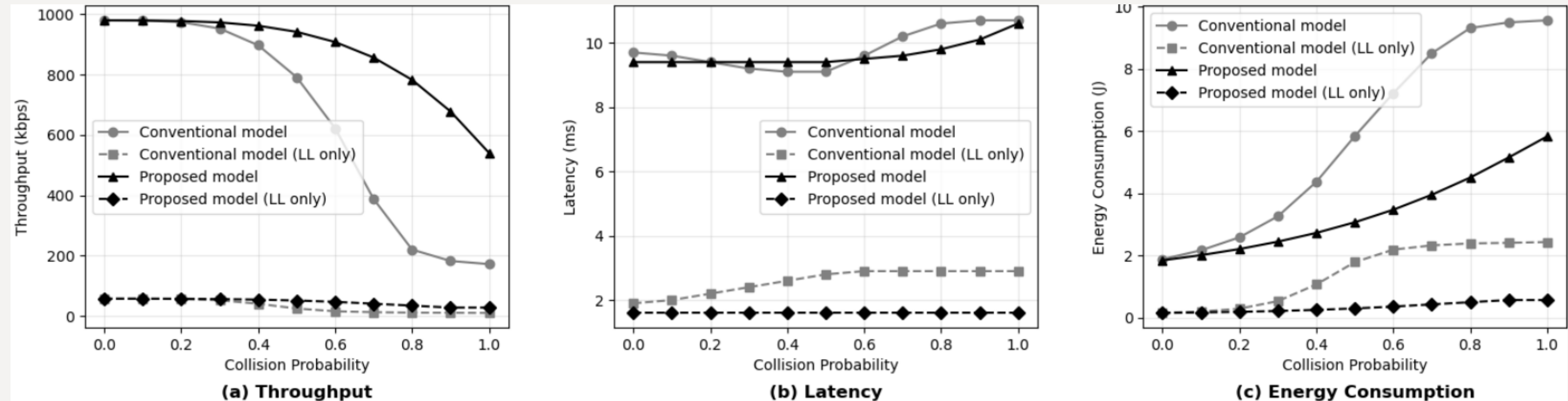
(c) Energy Consumption

Scenario 2. The ratio of low-latency STAs to high throughput STAs

- **Throughput:** Both models show a decrease as low-latency STA ratio increases, but the proposed model consistently outperforms the conventional model.
- **Latency:** Proposed model achieves up to 62.2% lower latency overall and an average 93.4% reduction for low-latency STAs, especially effective in dense low-latency environments.
- **Energy Consumption:** Both models consume less energy as low-latency STA ratio rises, but the proposed model provides an additional 51.2% energy savings on average.

Evaluation

Evaluation Results and Analysis



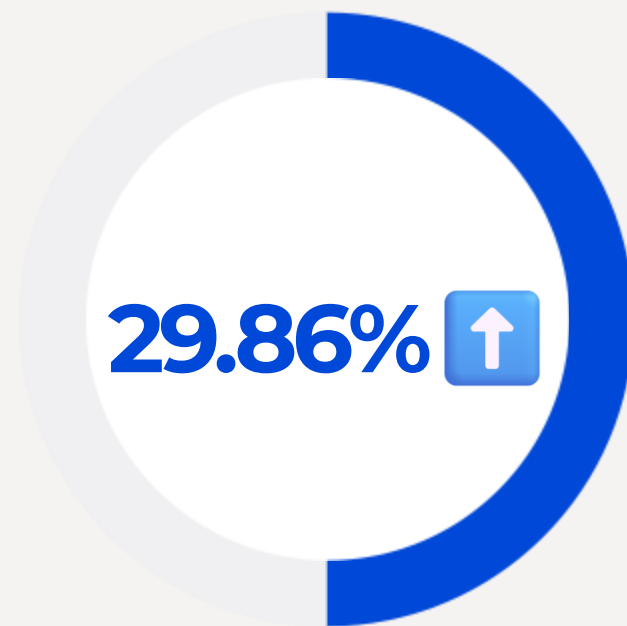
Scenario 3. The collision probability among STAs

- **Throughput:** Proposed model sustains higher throughput under increasing collision probability (540.8 kbps vs. 172.2 kbps for the conventional model).
- **Latency:** Proposed model maintains lower latency by separating low-latency and high-throughput traffic, even as collisions increase.
- **Energy Consumption:** Proposed model reduces energy usage by up to 51.62%, demonstrating effective energy-efficient operation under high collision probability.

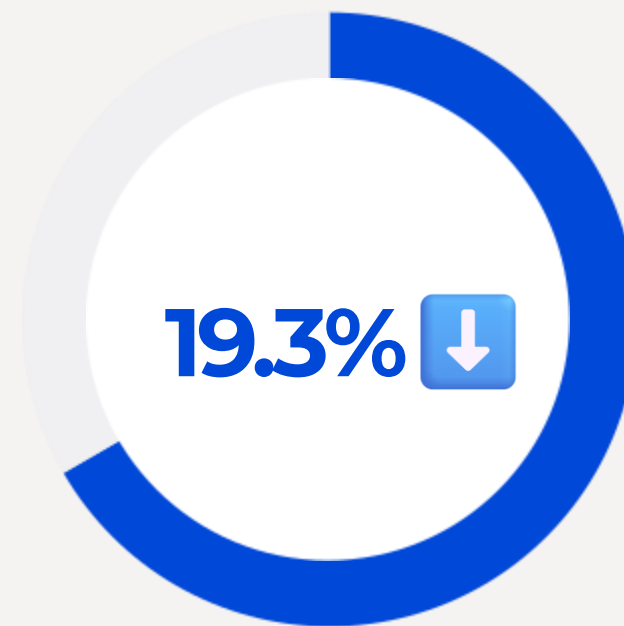
Conclusion

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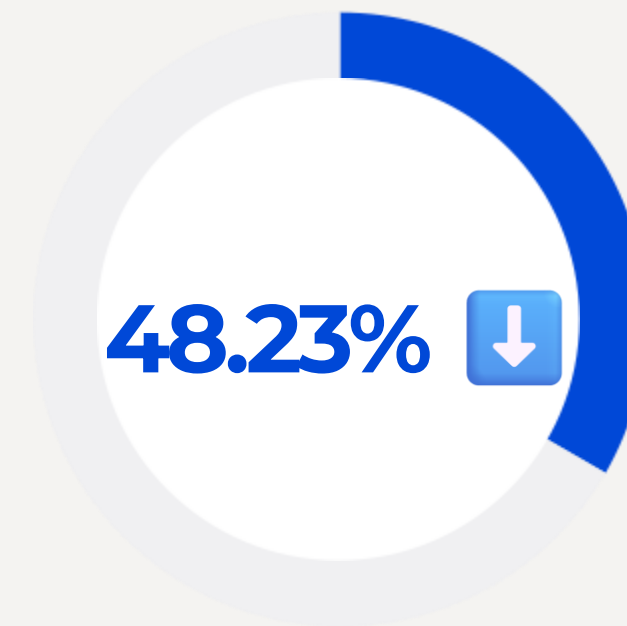
Performance improvements over conventional model:



Throughput



Latency



Energy consumption

Contribution

- Overcomes the limitations of the conventional RAW technique.
- Simultaneously ensures low latency and high throughput
- Enhances the availability and efficiency of IoT networks