ASEAN IVO Forum 2026

Low-Cost Dual-Receiver Wi-Fi Channel State Information Sensing of Human Presence and Respiration under Non-Line-of-Sight Conditions for Post-Disaster Search and Rescue

Full Name of Speaker:

Qintar Alifah Ristiana

Co-authors:

Suhono Harso Supangkat
Eueung Mulyana

Institut Teknologi Bandung, Indonesia



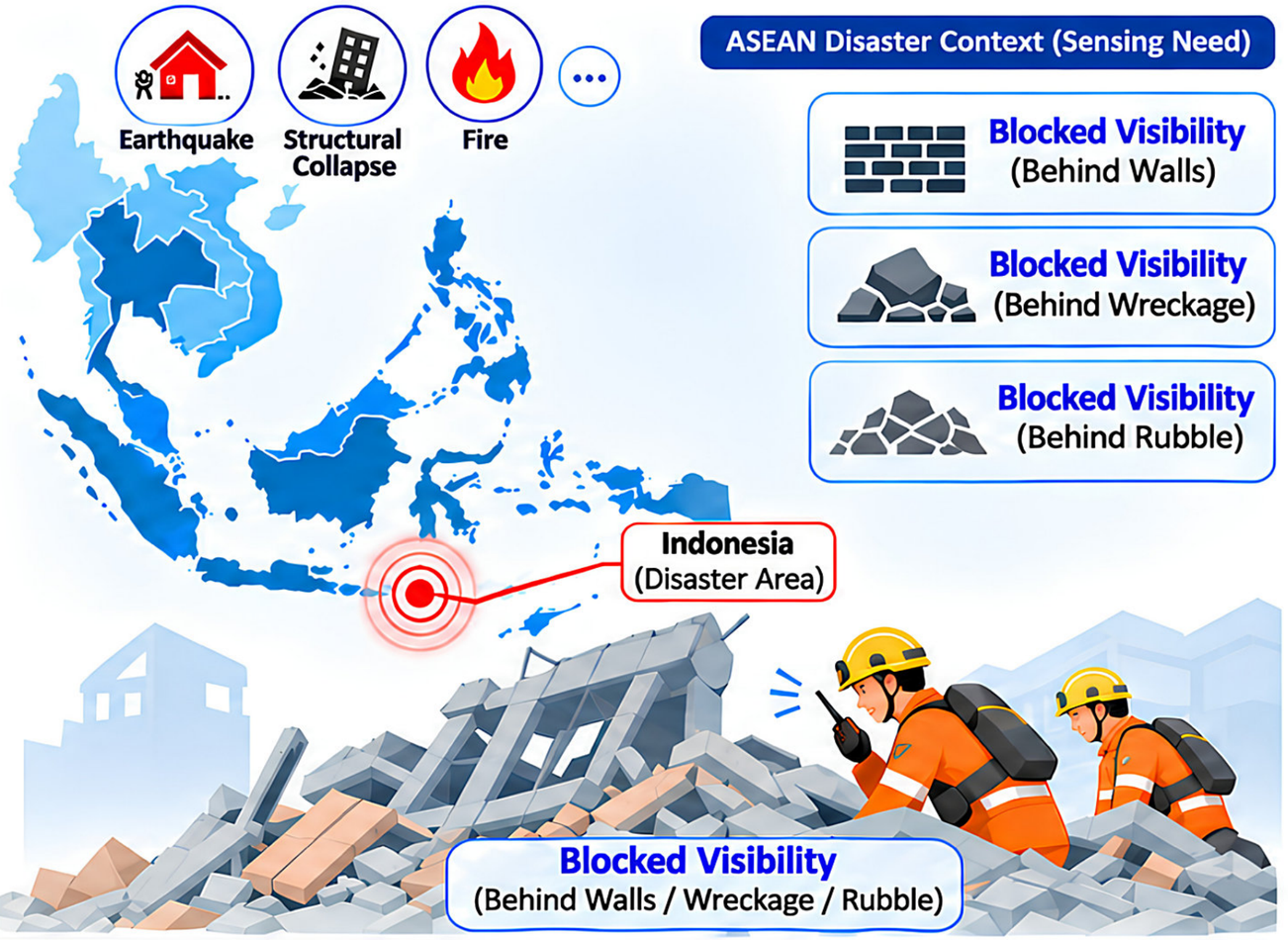
Background and Research Motivation

Background :

- Post-disaster **search and rescue (SAR)** often faces **blocked visibility** behind walls, **wreckage**, and rubble, making it difficult to locate and assess **survivors** in a timely manner [3]–[5].
- **Direct visual methods** (e.g., optical and infrared cameras) are **limited under occlusion,** as walls, **wreckage**, and low-visibility conditions can severely degrade or prevent target observation [5].
- **Device-free sensing** is attractive for disaster SAR because **survivors** do **not need to wear any devices,** which is practical when they are injured, unconscious, or otherwise unable to cooperate [1], [2].
- **Wi-Fi CSI** can capture **multipath changes** in the wireless channel caused by the human body, enabling the detection of human presence and physiological activities (e.g., respiration) even under non-line-of-sight (NLOS) conditions [1], [2].
- This work explores a **low-cost proof-of-concept** for **controlled NLOS presence** and **respiration sensing** using Wi-Fi CSI [1]–[5].

Targets:

- Develop a **low-cost, portable, device-free sensing prototype** using Wi-Fi CSI.
- Detect human **presence** and **estimate respiration** under controlled **non-line-of-sight (NLOS)** conditions.



References :

[1] Ma, Y., Zhou, G., & Wang, S. (2019). WiFi sensing with channel state information: A survey. *ACM Computing Surveys*, 52(3), 1–36.

[2] Abuhoureyah, F. S., Wong, Y. C., & Isira, A. S. B. M. (2024). WiFi-based human activity recognition through wall using deep learning. *Engineering Applications of Artificial Intelligence*, 127, 107171.

[3] Shi, C. et al. (2022). Multiple stationary human targets detection in through-wall UWB radar based on convolutional neural network. *Applied Sciences*, 12(9), 4720.

[4] Choudhary, P., Goel, N., & Saini, M, (2023). A survey on seismic sensor based target detection, localization, identification, and activity recognition. *ACM Computing Surveys*, 55(11), 1–36.

[5] Song, Z. et al. (2025). An infrared dataset for partially occluded person detection in complex environment for search and rescue. *Scientific Data*, 12(1), 300.

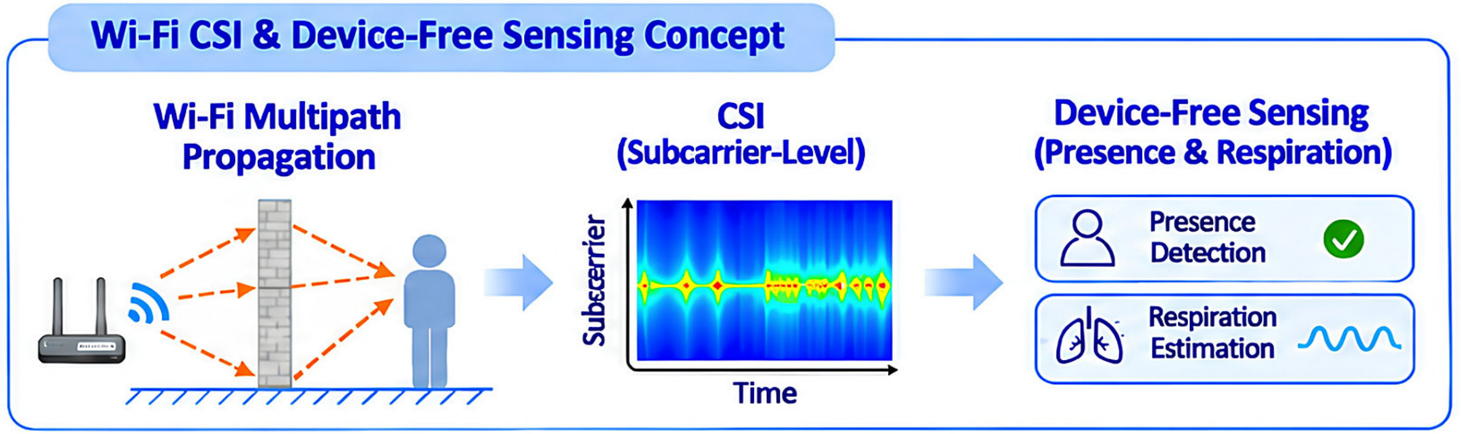
Background and Targets

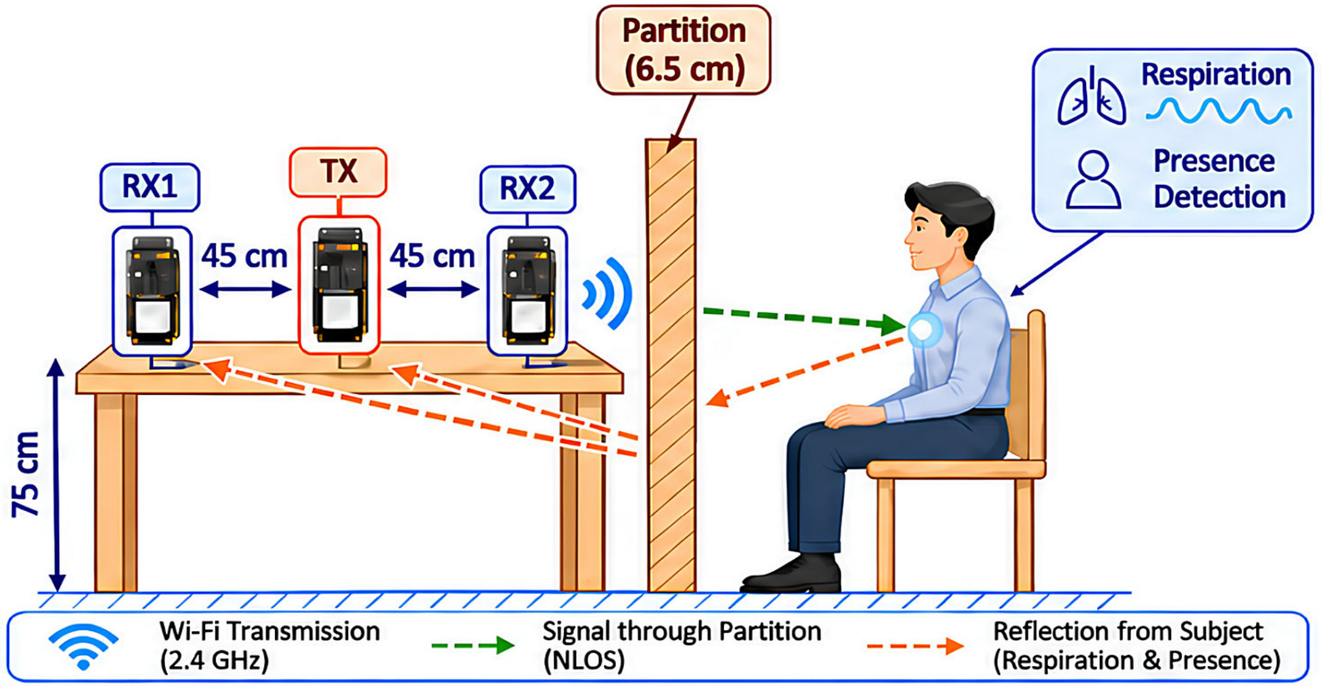
Background :

- Wi-Fi Channel State Information (CSI) provides **subcarrier-level measurements** of wireless-channel variations due to **multipath propagation** and **human-body interaction** [1].
- Device-free sensing (DFS) can **sense human behaviors and physiological signals without worn sensors**, using only ambient Wi-Fi signals [2].
- Prior work has demonstrated the effectiveness of Wi-Fi CSI for human sensing, including presence detection, respiration monitoring, and activity recognition [3], while this study focuses on a **controlled proof-of-concept** to validate the feasibility under a well-defined setup.

Targets :

- Stabilize CSI acquisition through **iterative experimental refinement** across sessions.
- Use a **dual-receiver configuration** (1 transmitter + 2 receivers) to exploit **link diversity**.
- Detect **presence** with a low-capacity **logistic classifier** on three CSI ratio features.
- Estimate **respiration rate** from the dominant **spectral peak** that reflects periodic chest motion.





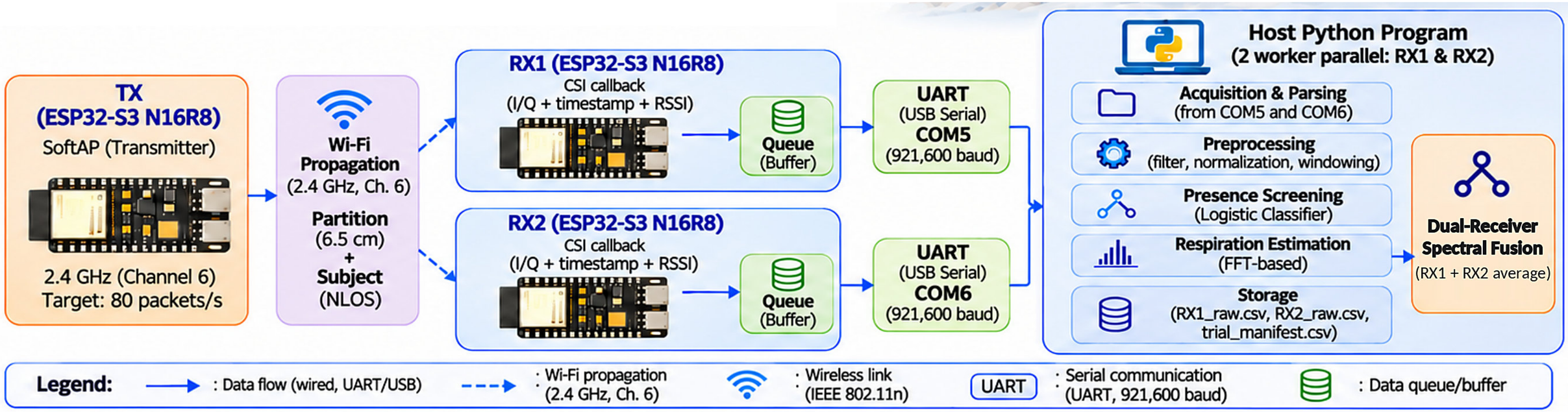
References :

[1] Ma, Y., Zhou, G., & Wang, S. (2019). WiFi sensing with channel state information: A survey. *ACM Computing Surveys, 52*(3), 1–36.

[2] Wei, Z. et al. (2025). A survey on WiFi-based human identification: Scenarios, challenges, and current solutions. *ACM Transactions on Sensor Networks*, 21(1), 1–32.

[3] Yue, B. et al. (2026). Deep learning–enhanced human sensing with channel state information: A survey. *Computers, Materials & Continua*, 86(1), 1.

Proposed Method: System Concept and Hardware Platform



System Overview

- **Hardware platform:** 3 ESP32-S3 N16R8 nodes (1 transmitter: TX / SoftAP, 2 receivers: RX1 and RX2).
- **Wireless setup:** 2.4 GHz Wi-Fi, channel 6, target acquisition rate 80 packets/s.
- **Receiver outputs:** CSI callback containing in-phase and quadrature (I/Q) values, timestamps, and RSSI.

Host Processing and Fusion

- **Host-side ingestion:** RX1 and RX2 are connected by USB serial (COM5 and COM6) at 921,600 baud to a host Python program.
- **Host processing pipeline:** acquisition/parsing, preprocessing, presence screening (logistic classifier), respiration estimation (FFT-based), and storage.
- **Link diversity:** respiration peaks from RX1 and RX2 are averaged, reducing the estimation error compared with a single CSI link.

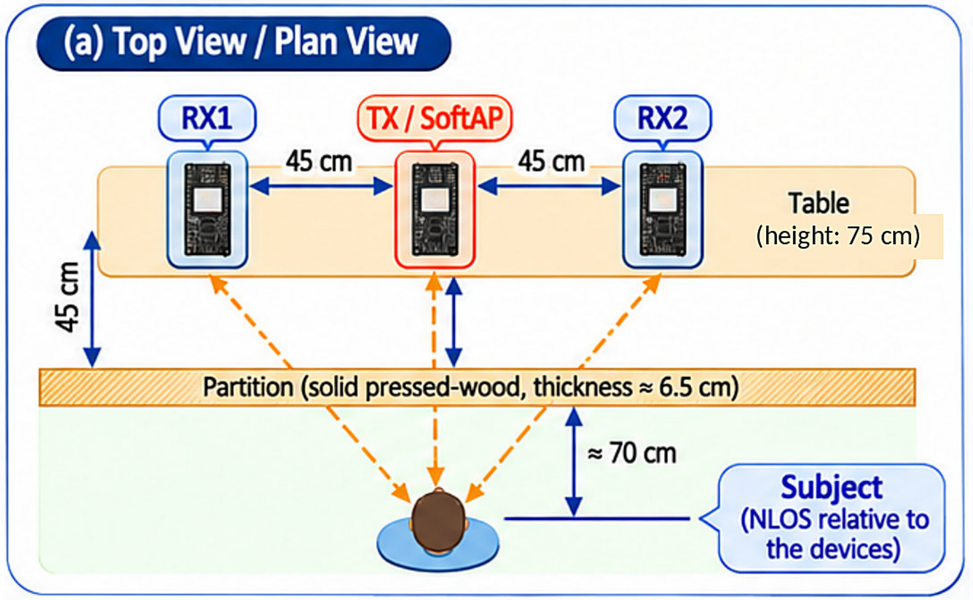
Proposed Method: Controlled NLOS Experimental Setup

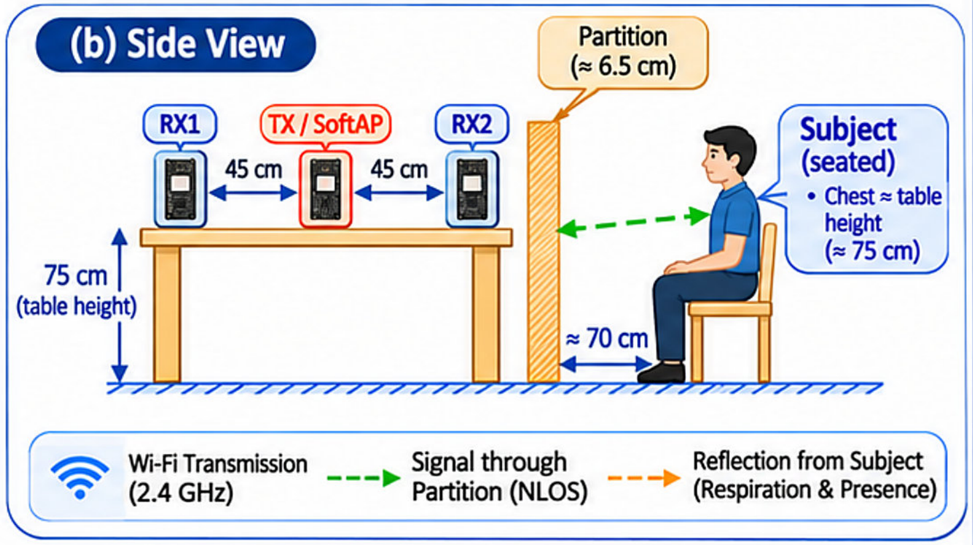
- The setup is a controlled proof-of-concept NLOS configuration for presence and respiration sensing.
- The geometry is fixed during a trial (i.e., nodes, partition, table, and subject positions remain unchanged) to ensure a consistent and reproducible configuration.

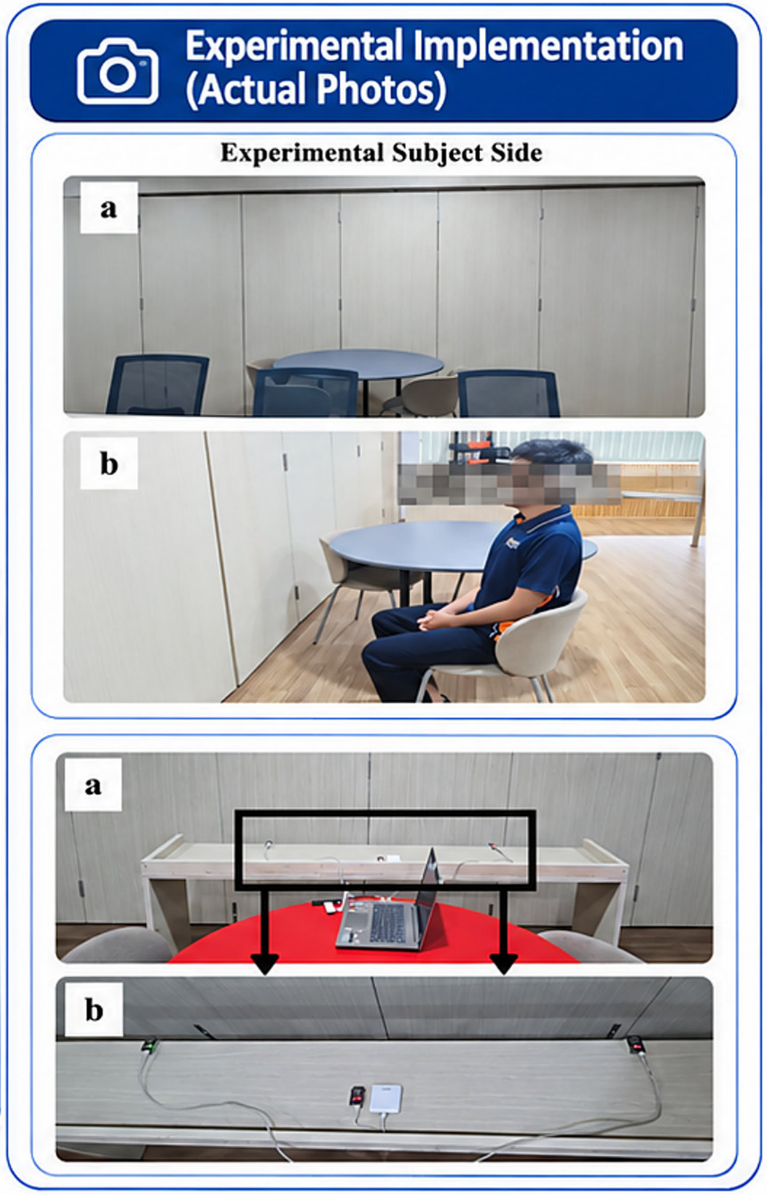
Field testing (next stage)

Not yet performed: all results come from a controlled indoor NLOS setup. Next: more subjects, rubble-like barrier materials, and field-like SAR scenarios.

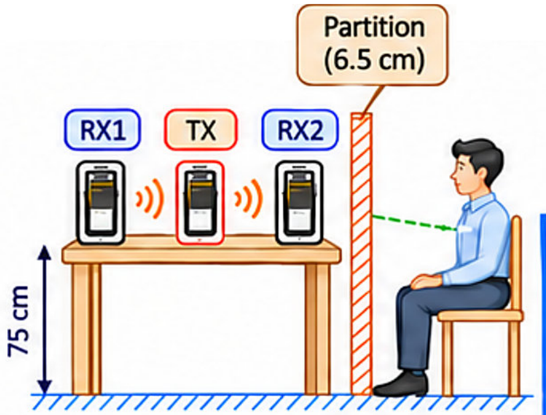
Geometry is fixed during a trial.







Proposed Method: Signal Processing and Decision Pipeline



1 CSI Acquisition (RX1 & RX2)

RX1 RX2

Acquire complex CSI
(I/Q + timestamp)
(Survey: WiFi CSI)

2 CSI Conversion & Resampling

I/Q → |CSI|

Convert to amplitude and resample onto a uniform time grid

3 Preprocessing

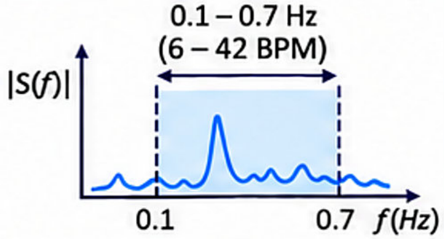
- Normalize
- Detrend
- Band-pass filter (0.1 – 0.7 Hz)

4 Subcarrier Selection

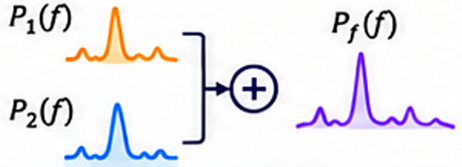
52 active subcarriers

Keep indices 1–26 and 38–63 on each receiver (RX1, RX2)

5 FFT (Respiration Band)



6 Dual-Receiver Spectral Fusion



Per-receiver median FFT peak, averaged across RX1 and RX2

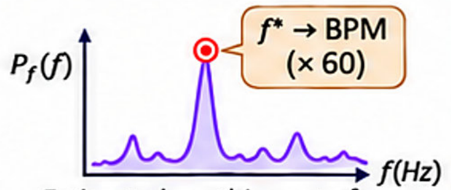
7 Presence Screening (Logistic Classifier)

$P(y = 1 \mid z) = \sigma(w^T z + b)$

Empty Room | Human Present

Logistic classifier on 3 CSI ratio features (30-s windows, threshold 0.5) to decide EMPTY vs. HUMAN

8 Respiration Estimation



Estimate breathing rate from the dominant peak frequency

Presence Detection

Empty Room / Human Present

Respiration Rate

Breathing Rate (BPM)

9 Ground Truth

Video-assisted manual breath counting (for human-present trials)

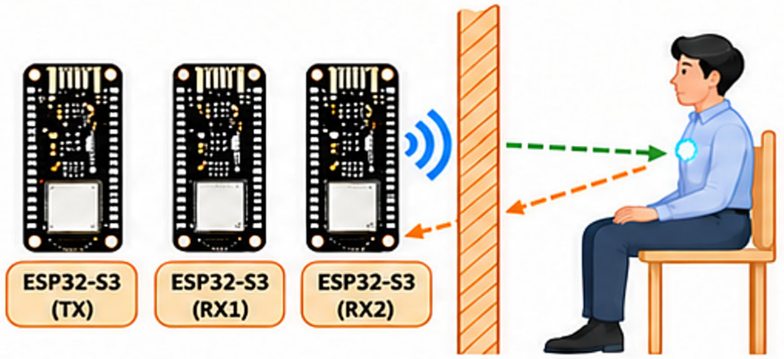
■ **Iterative sessions S01–S07** were used to stabilize acquisition, expand scenarios, and refine the proof-of-concept pipeline.

Legend: → : Processing flow | : Signal processing step | : Ground truth (reference) | : Output (result)

Impact: Scientific, Societal, and Collaborative Relevance

Scientific and Technological Impact

- Demonstrates a **low-cost dual-receiver Wi-Fi CSI** sensing concept under non-line-of-sight conditions.
- Integrates **presence screening** and **respiration estimation** in an edge-oriented pipeline.
- Shows how **commodity ESP32-S3 hardware** can be used for practical experimental survivor sensing research.



Societal Impact

- Addresses a **real SAR need**: identifying possible survivors when direct visual access is **blocked** (e.g., by debris, smoke, or darkness).
- Offers a **portable and relatively affordable** sensing concept that may be useful in resource-constrained settings.
- Supports **safer and faster triage** by providing an additional non-contact sensing layer.



Collaborative Impact

- Enables **joint validation** with **SAR teams** and **ASEAN research partners**, complementing radar, thermal, acoustic and seismic sensing.

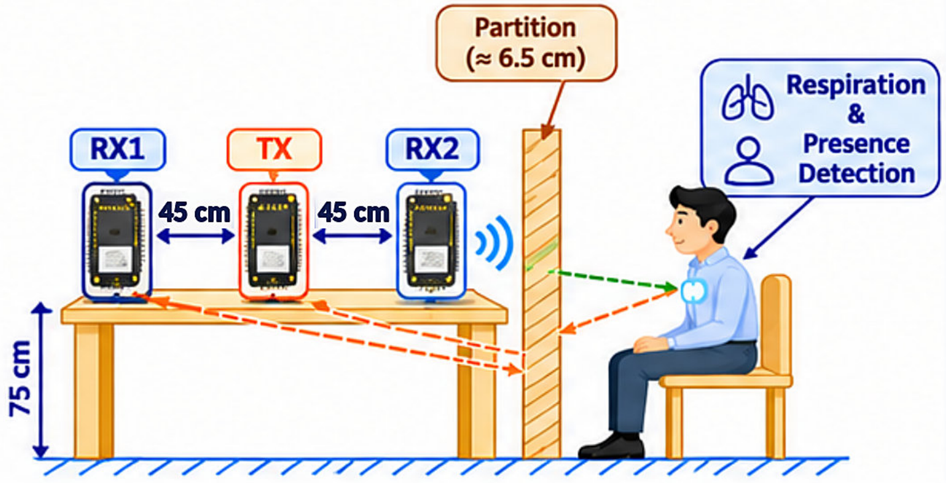


Complementary Sensing for More Reliable SAR Operations

Output/Outcome: Proof-of-Concept Results

Experimental Setup & Validation

- A Wi-Fi CSI prototype using **ESP32-S3 N16R8** for **NLOS human sensing**.
- One transmitter and **two receivers** placed outside a rigid **pressed-wood partition** (≈ **6.5 cm**).
- Final evaluation (S08, frozen model): **14 trials** for presence (11 human, 3 empty) and **8 trials** for respiration.
- The system detects human presence and estimates respiration rate from fused dual-receiver CSI.



Presence Detection Performance

Accuracy	Precision	Recall	Specificity	F1-Score	ROC-AUC	Balanced Accuracy
85.71%	84.62%	100%	33.33%	91.67%	0.970	66.67%

Confusion Matrix

		Predicted: Human (1)	Predicted: Empty (0)
Actual	Human (1)	11	0
	Empty (0)	2	1

- **11** True Positives (TP)
- **1** True Negative (TN)
- **2** False Positives (FP)
- **0** False Negatives (FN)

Respiration Estimation

MAE	RMSE	Bias	Pearson r	p-value	LoA
0.875 BPM	1.146 BPM	+0.875 BPM	0.9946	3.84×10^{-7}	−0.675 to +2.425 BPM

Key Takeaways

- The system achieved **promising presence detection** (F1-score 91.67%, ROC-AUC 0.970); specificity (33.33%) remains limited, with only 3 empty trials in the final test.
- Respiration rate was estimated with high correlation to ground truth (**r = 0.9946**) and a small error (**MAE = 0.875 BPM**).
- Results indicate the **feasibility of a low-cost, portable, ESP32-S3-based** Wi-Fi CSI system for NLOS human sensing as a potential **SAR support node**.

Output/Outcome: Research Outputs and ASEAN Collaboration Direction

Scientific Outputs

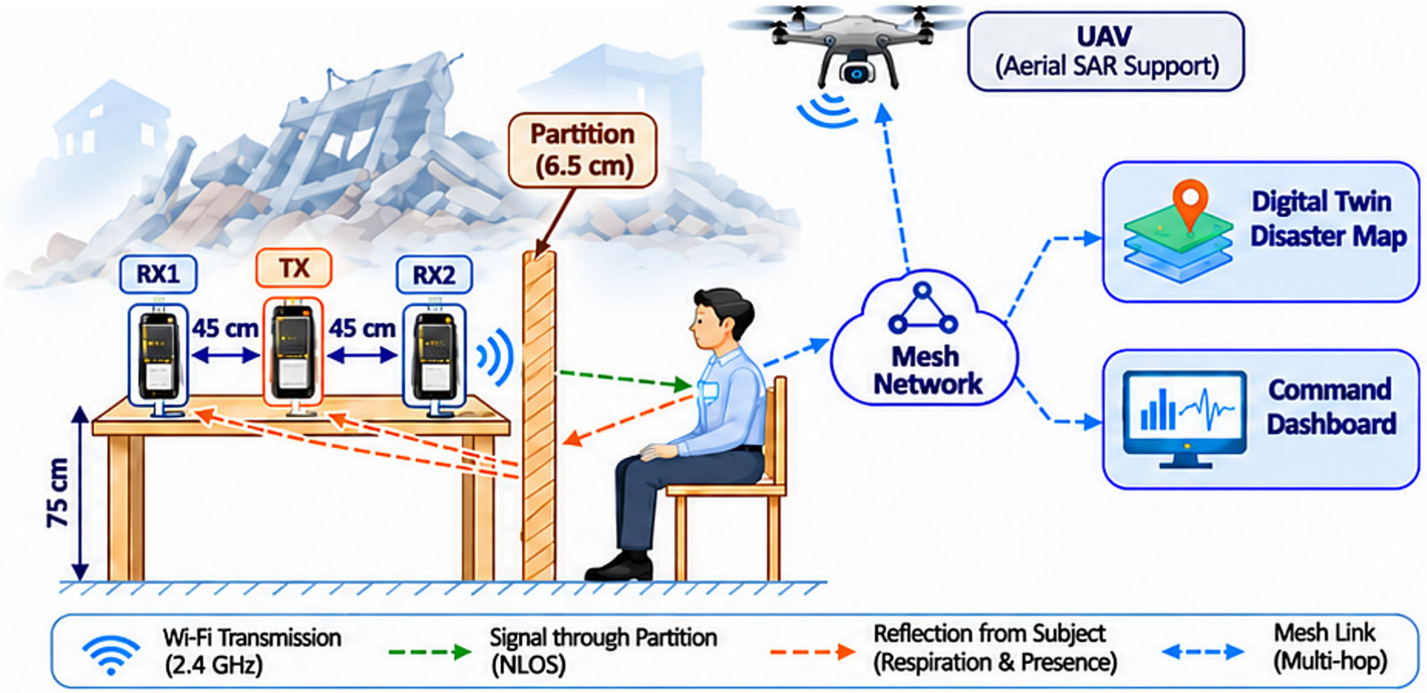
- A **reproducible controlled NLOS acquisition setup** using low-cost ESP32-S3 N16R8 devices.
- An **edge-oriented CSI processing pipeline** that combines dual-receiver diversity, presence screening, and respiration estimation.
- **Preliminary proof-of-concept performance data** that can guide future refinement.

Societal Outputs

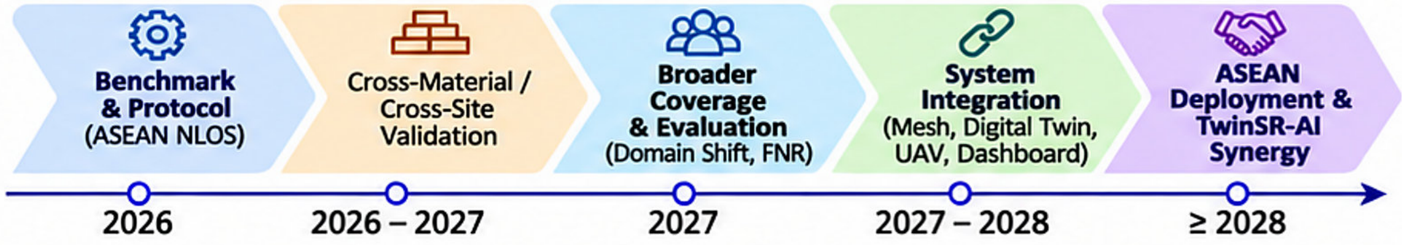
- A candidate **non-visual sensing layer** for future SAR support nodes.
- A concept that may later be integrated into **command dashboards** or **rapid assessment workflows**.

Collaborative Outputs and Future Direction

- An **ASEAN NLOS survivor-sensing benchmark** concept with a shared acquisition protocol.
- **Cross-material and cross-site validation** on wood, brick, concrete, and heterogeneous debris.
- Broader **participant and body-orientation** coverage.
- Evaluation of **domain shift** and **false-negative rate**.
- Potential integration with **mesh communication, digital-twin disaster maps, UAV platforms,** and **command dashboards**.
- This sensing approach could **complement ASEAN IVO** initiatives such as **TwinSR-AI** by adding a non-visual physical sensing layer.



ASEAN Collaboration Roadmap (Forward-Looking Direction)



Conclusion

1. Targets

- Develop a low-cost complementary survivor-sensing prototype for Non-line-of-sight conditions relevant to post-disaster search and sescue.

2. Method (idea)

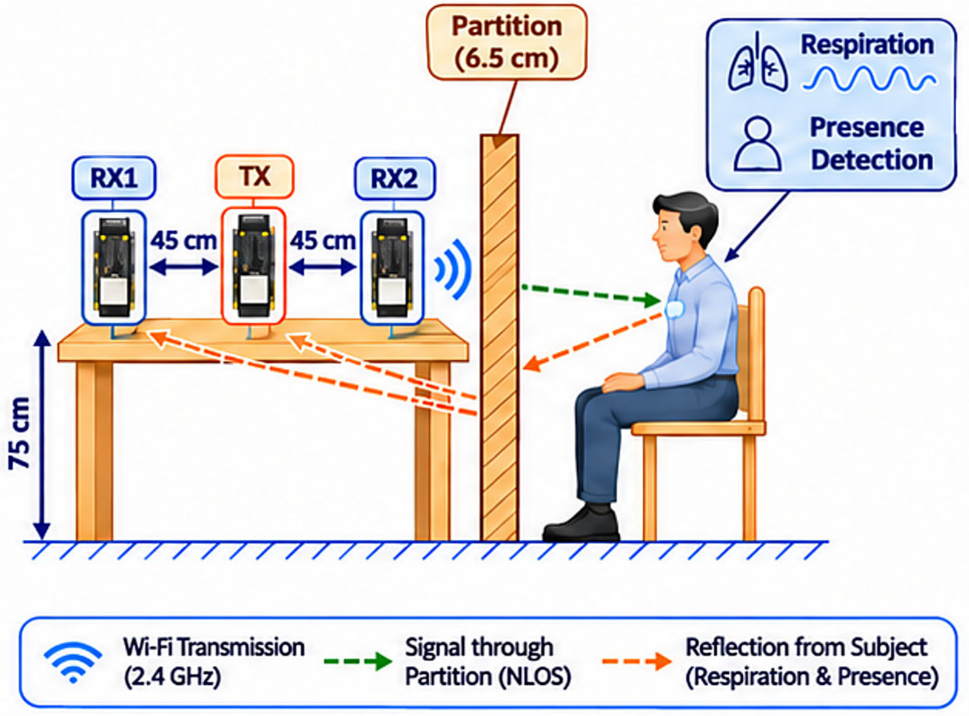
- Use 1 transmitter and 2 receivers based on ESP32-S3 N16R8 Wi-Fi CSI sensing.
- Combine dual-receiver spectral evidence and estimate respiration via FFT-based peak analysis.

3. Scientific and societal impact

- The controlled proof-of-concept shows successful presence screening and promising respiration estimation under one limited configuration.
- The approach offers an affordable additional sensing layer that may support faster and safer survivor search.

4. Next steps

- Validate across more people, positions, materials, and field-like scenarios.
- Strengthen generalization, quantify false negatives, and integrate with larger ASEAN disaster-response platforms.



Wi-Fi CSI will not replace rescue expertise, but can become an affordable additional sensing layer for faster and safer survivor search.