

Background :

1. The **indigenous people and the rescue operators in remote and dangerous vicinities** cannot profit from the use of intelligent wearable health support system due to **limited connectivity**
2. Current wearables have multiple measurements from Physio and Psychological sensors but **not supported by edge-intelligence** to be analyzed together
3. Current wearables are for individual purposes and **not for common monitoring and intervention purposes**

Targets :

1. Working P2EI-Wealth Prototype using LoRA connected to a portable data center
2. Edge Intelligence model for the physio and psychological measurements and correlation establishment
3. Test and analysis using **2 use cases**
 1. Remote indigenous area (Tasik Chini, Malaysia)
 2. ~~Disaster recovery operation (Quezon City, Philippines)~~



Speaker :

Project Leader - Asma Abu-Samah
Wireless Research@UKM, Universiti Kebangsaan Malaysia (UKM)

Project Members :

Members	Institution
Asma' Abu-Samah	UKM, Malaysia
Rosdiadee Nordin	UKM, Malaysia
Nor Fadzilah Abdullah	UKM, Malaysia
Mohd Radzi Ab Rahim	PPTC and UKM, Malaysia
Reginald J. M. Mercado	GTek Enterprise, Philippines
Xarxes C. Alejos	GTek Enterprise, Philippines
Jennifer C. De La Cruz	Mapua University, Philippines
Glenn V. Magwili	Mapua University, Philippines
Emoto Hiroshi	NICT and ASEAN-IVO, Japan



Project Duration : 18+12 (ext.) Months (01/06/2022 – 31/12/2024)

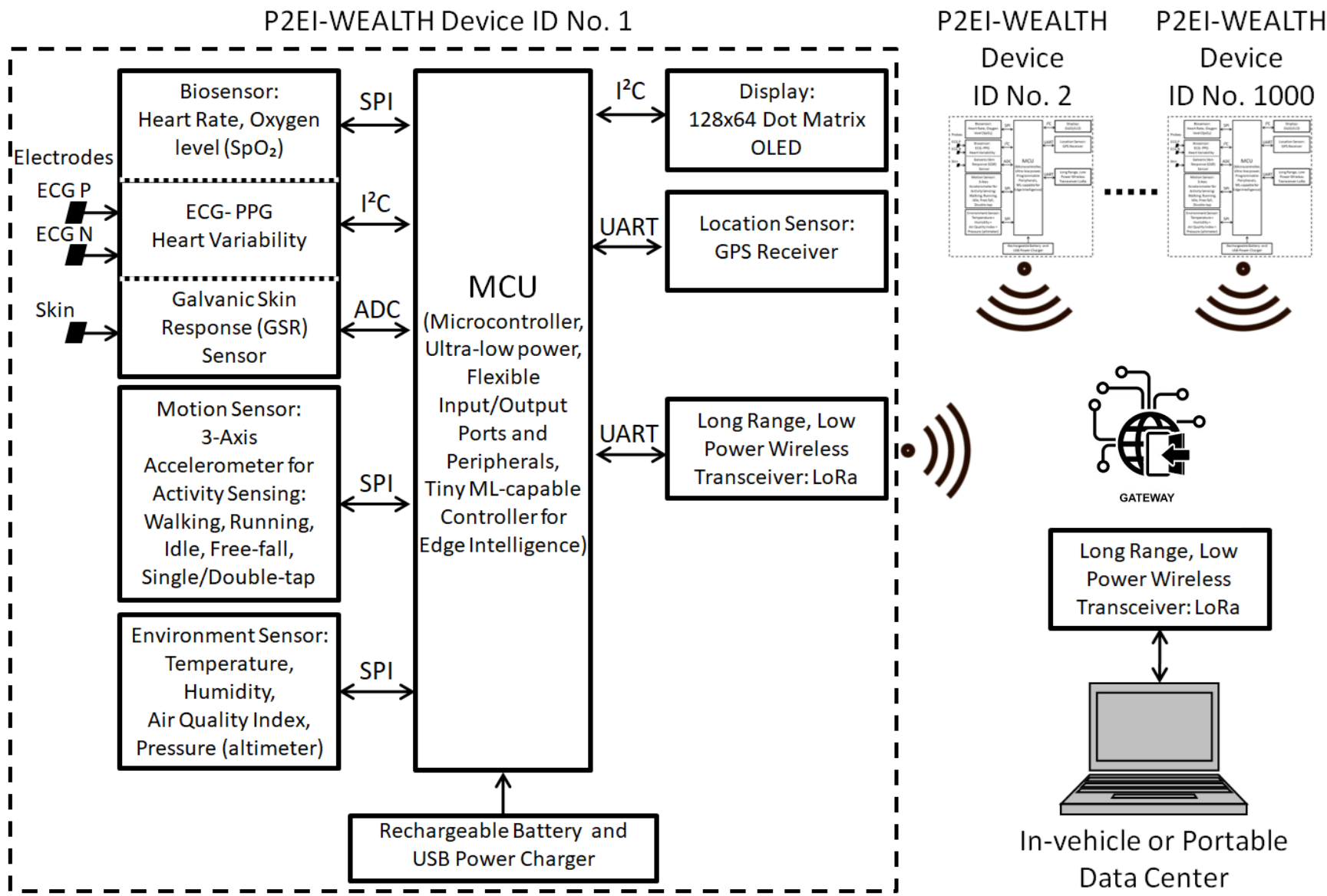
Project Budget (40,260 USD):
 Expense of 21/10/2024 = 18,494 USD
 Balance of 21/10/2024 = 9,300 USD

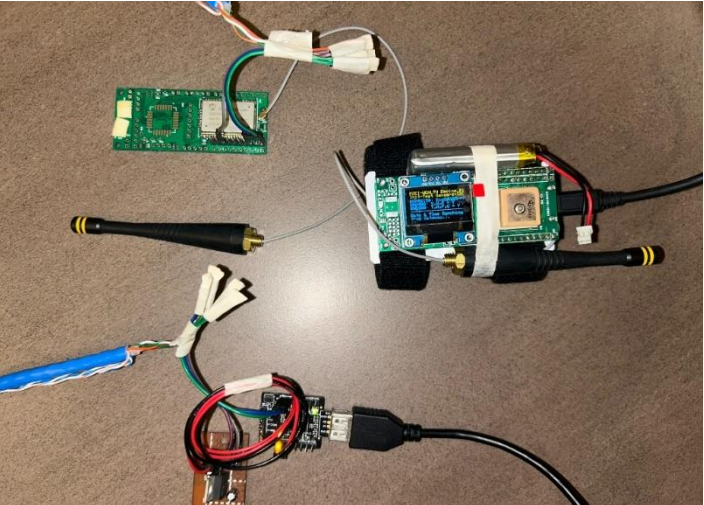


P2EI-WEALTH
(Physiological and Psychological Edge Intelligence WEArable LoRa Health) System

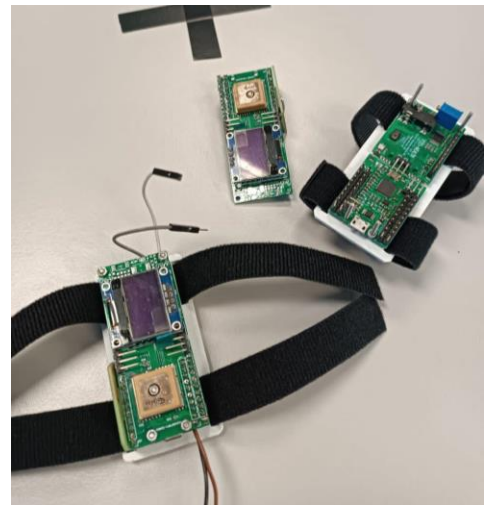
Overview of the proposed P2EI-WEALTH system & Research Activities

- 1. Technological development:**
 - P2P LoRa-based Hardware prototype
- 2. Experiments including field testing**
 - Network Planning
 - LoRa Propagation Modeling
- 3. Scientific development**
 - Psychological Edge models





The P2P Devices (End-Nodes and the Gateway)



Briefing by Mr. Reggie (Gtek) to deans of MU



Visit, test and survey of the watch with the indigenous communities

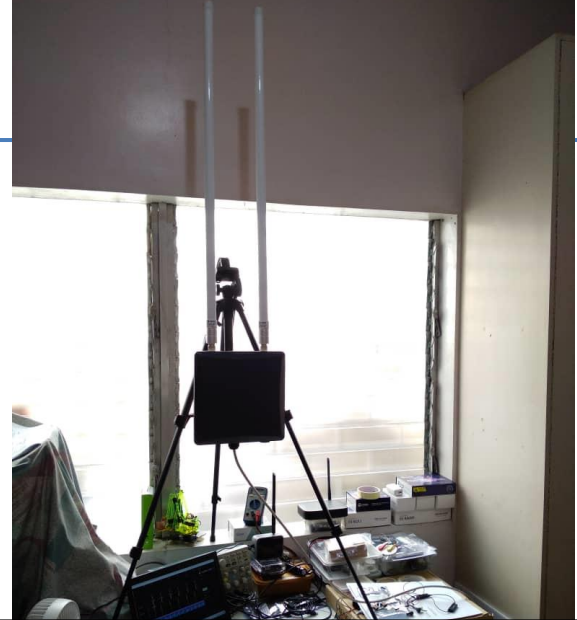


Visit to the Quezon City Disaster Risk Reduction and Management Office (QCDRRMO) for the feedback and the improvement of device

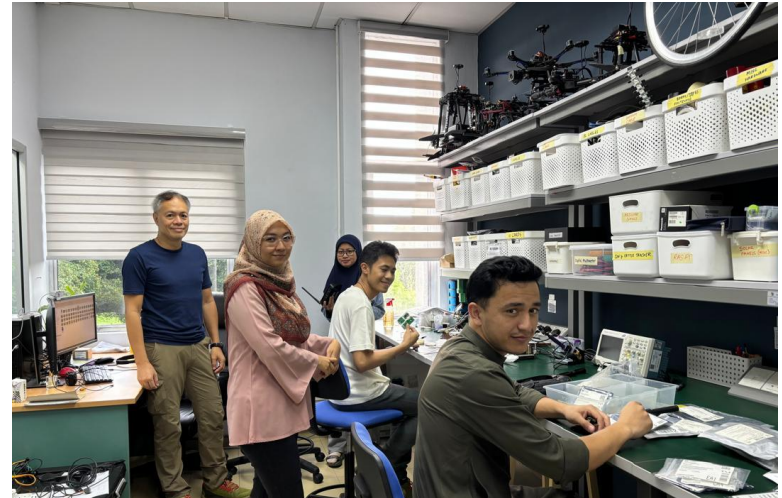




Workshop 1 (10th-12th July, 2023)



Merging the LoRaWAN protocol with the developed P2EI-WEALTH Protocol
(Unsuccessful yet)

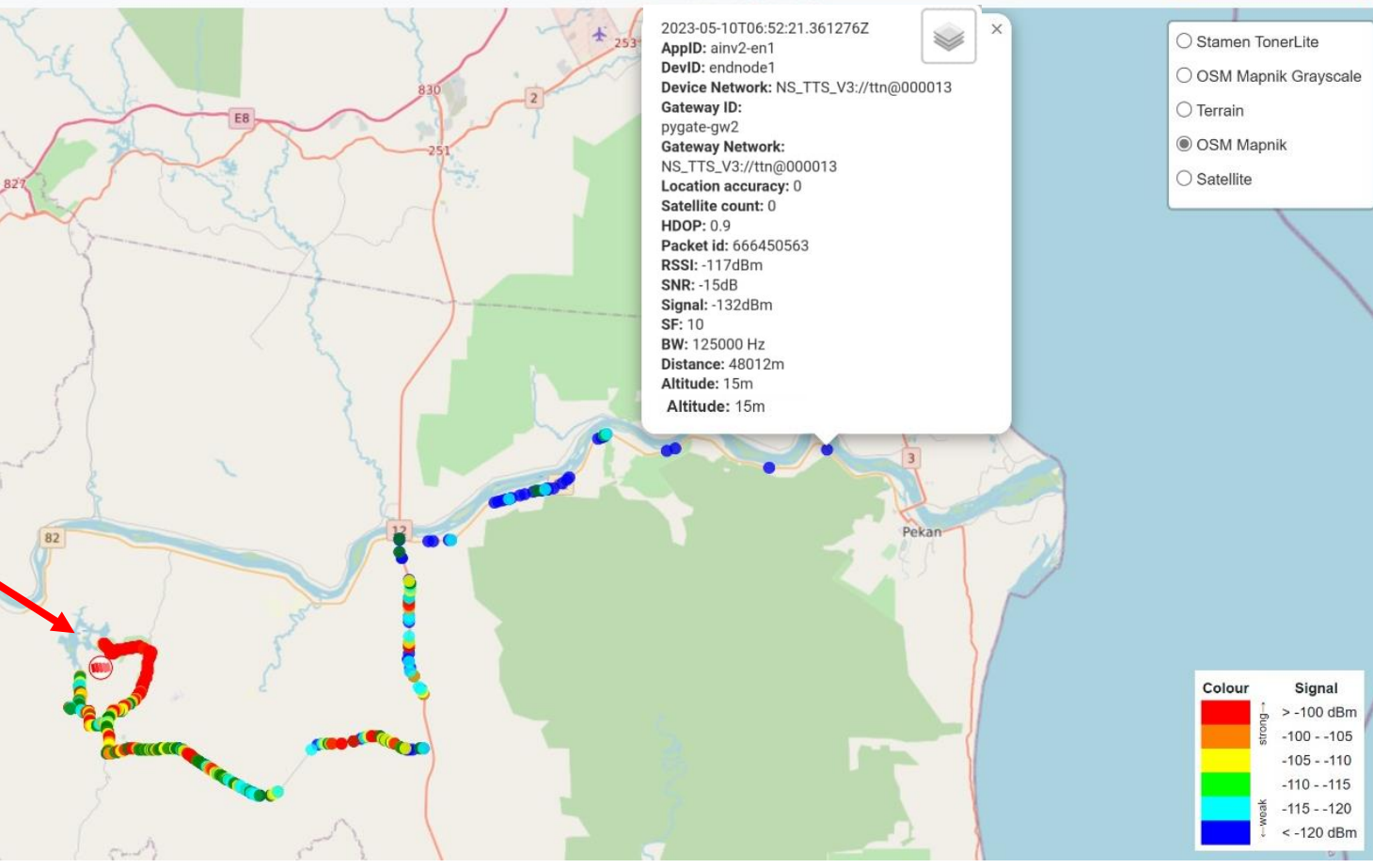


Workshop 2 (19th-23rd August, 2024)

Installement of LoRa Gateway on identified point in Mount Ketaya at 208m ASL by Dr. Fadzilah



Measurement using 3 different end nodes (EN), including a proprietary (RAK Wireless) field tester



1 packet of 10 bytes
Furthest point reached at 48.012km
Gateway: 8dbi fiberglass, vertical polarized antenna
EN: 3dbi antenna, Using Pycom-based EN with SF-10

Brainstorming of measurement plans in Chini (3rd-5th July, 2023)



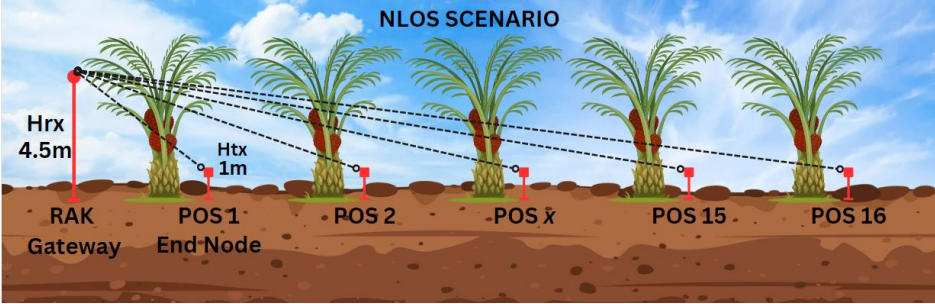
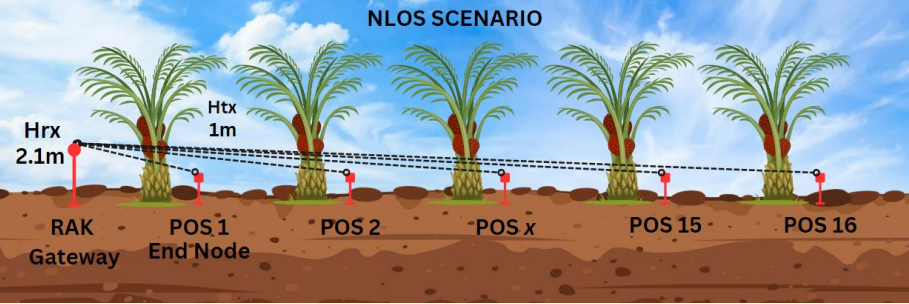
Brainstorming of measurement plans in Chini (26th -30th August, 2024)



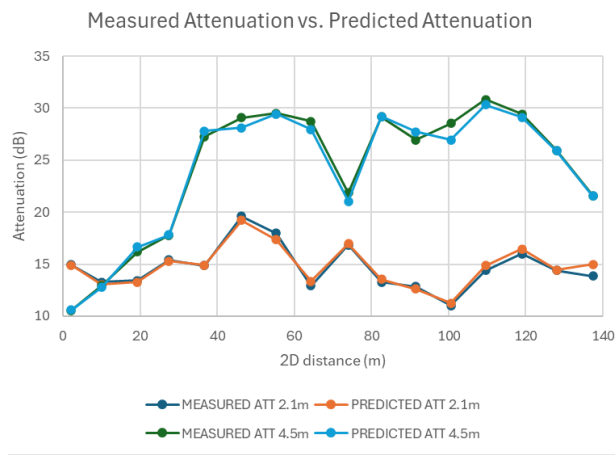
Mount of permanent structure for Bukit Ketaya by Prof. Rosdiadee



Testing using P2P protocol developed by Mr. Reggie (Gtek)



Specification	Description
Type of model	Optimizable Tree
No. of features	8
Cross-validation method	10-fold cross-validation
Training/testing split	80% training, 20% testing
PCA (principal component analysis)	At least 95% variance
Optimization method	Bayesian optimization
Specification	Description
Type of model	Optimizable Tree

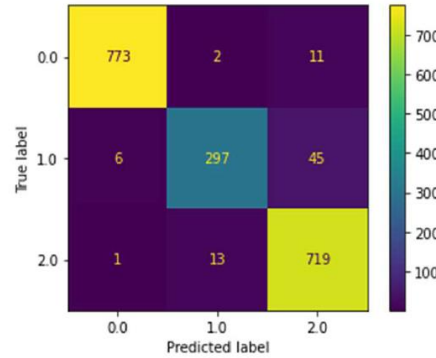


Measurement in the palm plantation using LOS and NLOS configurations (April-July 2024)

Machine learning-based propagation model development

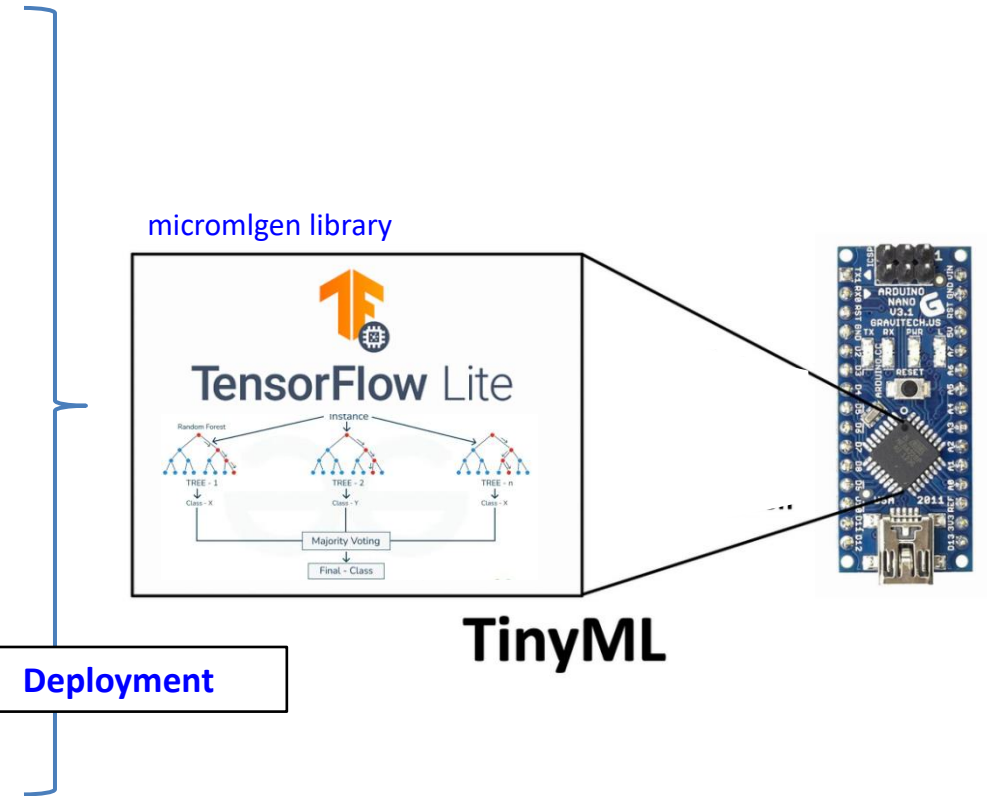
Evaluation results for multiple algorithms for Nurses Dataset [1]

Algorithms	Accuracy (%)	Precision	Recall	F1 Score
Support Vector Machine	72.95	0.8500	0.6455	0.6225
Adaboost	71.45	0.7077	0.6503	0.6569
Random Forest	91.69	0.9164	0.8885	0.9164
Bootstrapping	95.82	0.9933	0.9802	0.9469



Evaluation results for multiple algorithms for WESAD dataset [2]

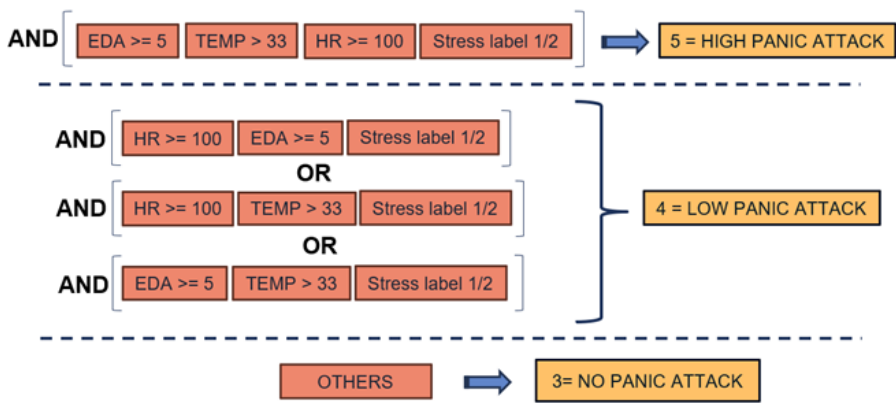
Model	Quantization	PCA	Hyper-parameters	Hyperparameter Settings	Model accuracy	Size of model
Random Forest	Yes	Yes	<ul style="list-style-type: none"> criterion max_depth n_estimators 	<ul style="list-style-type: none"> gini none 100 	96%	2.5 GB
Random Forest	Yes	Yes	<ul style="list-style-type: none"> criterion max_depth n_estimators 	<ul style="list-style-type: none"> gini 15 100 	92%	213.7 MB
Random Forest	Yes	Yes	<ul style="list-style-type: none"> criterion max_depth n_estimators 	<ul style="list-style-type: none"> entropy 7 50 	73%	1.5 MB
Decision Tree	No	Yes	<ul style="list-style-type: none"> criterion 	<ul style="list-style-type: none"> gini 	46%	Not extracted



[1] Hosseini, S., Gottumukkala, R., Katragadda, S., Bhupatiraju, R. T., Ashkar, Z., Borst, C. W., & Cochran, K. (2022). A multimodal sensor dataset for continuous stress detection of nurses in a hospital. *Scientific Data*, 9(1), 255.

[2] Schmidt, P., Reiss, A., Duerichen, R., Marberger, C., & Van Laerhoven, K. (2018, October). Introducing wesad, a multimodal dataset for wearable stress and affect detection. In *Proceedings of the 20th ACM international conference on multimodal interaction* (pp. 400-408).

Project Activities and Results (3): Prediction model for Panic Attack



Establishment of Panic Attack Classes

Machine Learning Model	Accuracy and Respective Nurses Dataset		
	Training (Full 12') Data	Validation (10% of 12') Data	Testing (3 Selected) Data
	(943718)	(104857)	(903752)
Fine Tree	100%	100%	99.96%
Medium Tree	100%	100%	99.96%
Coarse Tree	94.94%	94.89%	82.44%
Fine KNN	100%	100%	87.58%
Medium KNN	99.98%	100%	87.58%
Coarse KNN	99.82%	99.85%	87.81%
Cosine KNN	99.99%	100%	88.44%
Cubic KNN	99.98%	100%	86.92%
Weighted KNN	100%	100%	87.57%
Efficient Logistic Regression	91.88%	91.81%	74.01%
Efficient Linear SVM	91.69%	91.68%	74.04%

Evaluation results for multiple algorithms for Nurses Dataset [1]

Machine Learning Model	Accuracy and Respective Nurses Dataset		
	Training (Full 12' Nurses Data)	Training (Full 12' Nurses Data)	Testing (3 Selected Nurses Data)
	(943718)	(943718)	(903752)
Fine Tree	Total cost : 0 Error rate : 0% Training time : 125.73s Model size : ~7kB Prediction speed : ~510000 obs/sec	Total cost : 0 Error rate : 0.0%	Total cost : 352 Error rate : 0.0%
Medium Tree	Total cost : 0 Error rate : 0% Training time : 118.67s Model size : ~7kB Prediction speed : ~570000 obs/sec	Total cost : 0 Error rate : 0.0%	Total cost : 352 Error rate : 0.0%
Coarse Tree	Total cost : 47743 Error rate : 5.1% Training time : 111.86s Model size : ~5kB Prediction speed : ~670000 obs/s	Total cost : 5361 Error rate : 5.1%	Total cost : 158723 Error rate : 17.6%
Coarse KNN	Total cost : 1736 Error rate : 0.2% Training time : 525.4s Model size : ~64MB Prediction speed : ~7800 obs/s	Total cost : 161 Error rate : 0.2%	Total cost : 110143 Error rate : 12.2%
Cosine KNN	Total cost : 130 Error rate : 0.0% Training time : 21571s Model size : ~44MB Prediction speed : ~690 obs/s	Total cost : 0 Error rate : 0.0%	Total cost : 104508 Error rate : 11.6%
Cubic KNN	Total cost : 159 Error rate : 0.0% Training time : 17347s Model size : ~64MB Prediction speed : ~2900 obs/s	Total cost : 3 Error rate : 0.0%	Total cost : 118200 Error rate : 13.1%
Weighted KNN	Total cost : 0 Error rate : 0.0% Training time : 305.97s Model size : ~64MB Prediction speed : ~17000 obs/s	Total cost : 0 Error rate : 0.0%	Total cost : 112319 Error rate : 12.4%
Efficient Logistic Regression	Total cost : 76665 Error rate : 8.1% Training time : 462.97s Model size : ~37kB Prediction speed : ~370000 obs/s	Total cost : 8589 Error rate : 8.2%	Total cost : 234907 Error rate : 26.0%
Efficient Linear SVM	Total cost : 78409 Error rate : 8.3% Training time : 345.08s Model size : ~37kB Prediction speed : ~420000 obs/s	Total cost : 8722 Error rate : 8.3%	Total cost : 234635 Error rate : 26.0%



SEKRETARIAT ETIKA PENYELIDIKAN UKM • UKM RESEARCH ETHICS COMMITTEE
 Reference : UKM PPI/111/8/JEP-2023-349
 Date : 21 September 2023

Dr. Asma' Abu Samah
 Department of Electrical, Electronic & Systems Engineering

Obtained approval for 18 Months, 18/09/2023 – 20/03/2025

ETHICAL APPROVAL TO CONDUCT RESEARCH IN THE NATIONAL UNIVERSITY OF MALAYSIA

Research title: P2EI-WEALTH (Physiological and Psychological Edge Intelligence WEARable LoRa Health) System for Remote Indigenous Community and Disaster Recovery Operations
 Ethics Ref. No.: JEP-2023-349
 Approval period: 18 September 2023 – 20 March 2025
 Study Site: Chini Lake, Pahang, Malaysia
 Sample Size: 10 Indigenous people

With reference to the above.

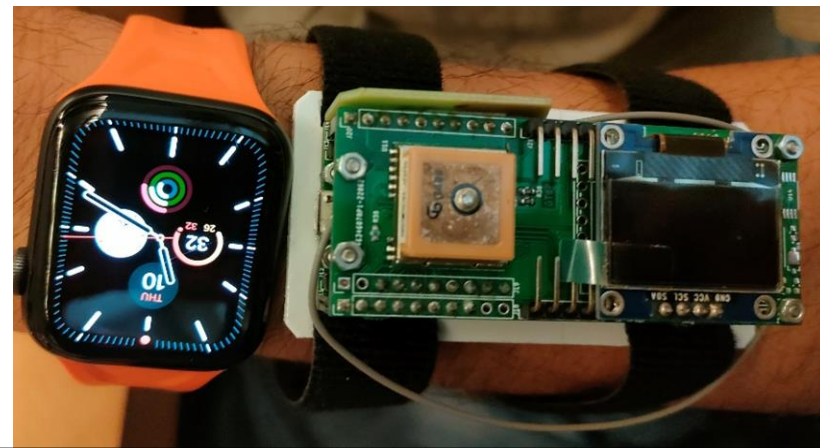
2. The Research Ethics Committee, The National University of Malaysia (RECUKM) has provided ethical approval for above study. Please be reminded permission from the Deputy Dean of research of the faculty or Director of Institute/Centre and all relevant heads of departments / units where the study will be carried out must be obtained prior to the study. You are required to follow and comply with their decision and all other relevant regulations.

3. Please note that the investigator's responsibility is to ensure that:
- i. All Adverse Events should be reported to RECUKM as soon as possible.
 - ii. Progress report should be submitted every **6 Months**.
 - iii. All changes / amendments to the study documents / study sites / study team must be notified to the RECUKM. All changes must be approved by RECUKM before continuation of the study.
 - iv. Application for renewal of the approval has to be submitted to RECUKM within one month (1 month) prior to the expiry of ethical approval.
 - v. Final Report should be provided to RECUKM when the project is complete.
 - vi. Please take note that all records and data are to be kept strictly CONFIDENTIAL and can only be used for the purpose of this study. All precautions are to be taken to maintain data confidentiality.

Required forms can be obtained from the The Research Ethics Committee, The National University of Malaysia (RECUKM) website: <https://www.ukm.my/jepukm>

Thank you.

Sekretariat Etika Penyelidikan Universiti Kebangsaan Malaysia
 Tingkat 1, Blok Klinik, Hospital Conselor Tuanku Muhriz, Pusat Penyelidikan UKM, Jalan Yacob Laif, Bandar Tun Razak, 56000 Cheras Kuala Lumpur.
 Telefon: +603-9145 5046 / 5048
 Email: sepu.km@ukm.edu.my Web: <https://www.ukm.my/jepukm/>
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Data from P2EI-WEALTH and EMPATICA Embrace Plus will be shared in Open Platforms (Kaggle and Github)



Identified immediate Future Collaboration with National Chin-Yi University, Taiwan and Universitas Makassar, Indonesia



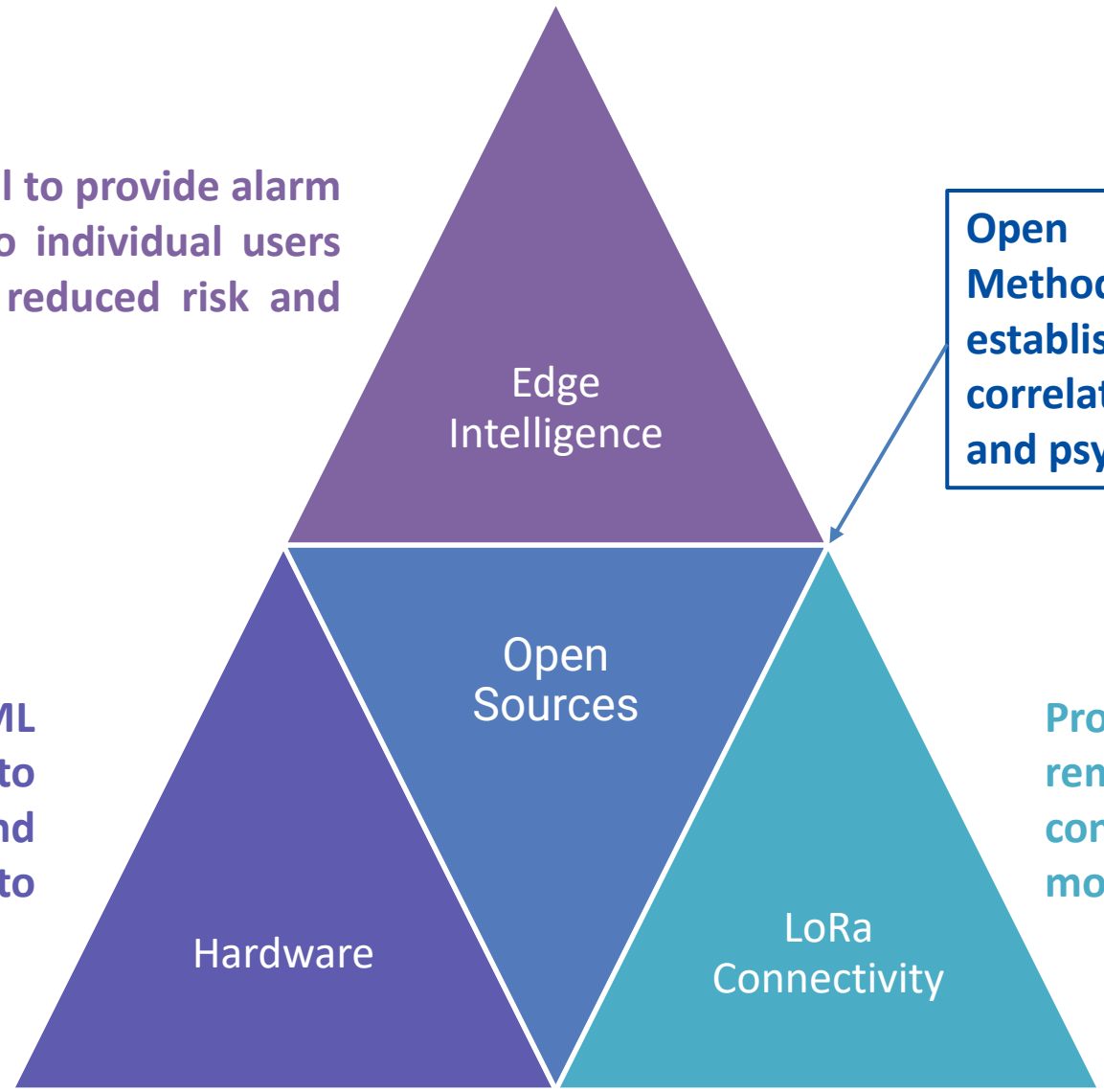


No:	Paper title:	Author names	Affiliation	Conference/Workshop name:	Conference date	Conference Venue
1.	Classification of stress using Machine Learning based on Physiological and Psychological Data from Wearables	Asma Abu-Samah, Jennifer Dela Cruz, Tuan Muhamad Affiq Aimullah Tuan Mohd Pauzi, Dalilah Ghaffa, Rosdiadee Nordin and Nor Fadzilah Abdullah	UKM, MU	IEEE HNICEM 2023 15th International Conference on Humanoid, Nanotechnology, Information Technology, Communication and Control, Environment, and Management	November 19-23, 2023	Coron, Palawan, Philippines
2.	Hybrid LoRa Network for Underserved Community Internet (LUCI)	Nor Fadzilah Abdullah (Presenter)	UKM	ICTP Workshop on Communication in Extreme Environments for Science and Sustainable Development	November 20-24, 2023	Trieste, Italy
3.	P2EI-WEALTH System for Remote Indigenous Community and Disaster Recovery Operation	Dalilah Ghaffa (Presenter)	UKM, G-Tek	ICTP-UNU Workshop on TinyML for Sustainable Development	April 26-30, 2024	Macau, Rep. of China
4.	Indigenous Community Connectivity: Enhancing LoRaWAN Performance through Machine Learning in Palm Oil Plantations	Nor Fadzilah Abdullah, Asma Abu-Samah, Ammar Zaid Norabid, Nur Hasinah Najiah Maizan, Haider A.H. Alobaidy, Rosdiadee Nordin	UKM	ICTC 2024: The 15 th International Conference on ICT Convergence	October 16-18, 2024	Jeju, Korea
5.	Application of Machine Learning for Panic Attack Detection using Health Wearable Sensors	Anis Najihah Abu Samah, Asma Abu-Samah, Nor Fadzilah Abdullah, Rosmina Jaafar	UKM	ICTC 2024: The 15 th International Conference on ICT Convergence	October 16-18, 2024	Jeju, Korea

1. [Application of Tiny Machine Learning for Stress Detection in Health Wearable Devices](#) (Target *IEEE Access*)
2. [Citizen Scientists Empowerment through Open Science and Internet of Things to Achieve Sustainable Development Goals: A Review and Future Directions](#) (Target *Elsevier IoT*)

Edge intelligence Model to provide alarm and health situation to individual users and rescue teams for reduced risk and interventions.

Expansion of TinyML (ML models which are optimized to run on very low-power and small footprint devices) to another use-case



Open test data and Open Methodology can be used to establish different studies correlating both physiological and psychological inputs

Provision of LPWAN connectivity in remote and disaster areas for continuous health and situation monitoring

Conclusion:

1. The project has successfully delivered the 3 objectives looking into the:
 1. Health wearable hardware design and development,
 2. Tested different stress and anxiety attack edge models using established open dataset, and
 3. Provision of LoRa network to the targeted community and the establishment of ML-based LoRa Propagation Model.
2. The project however cannot accomplish the potential extension that was discovered throughout its run:
 1. Merge the proprietary LoRa Gateway design with the established RAK Gateway and using existing server such as The Things Network, and
 2. Validated the edge models with medical experts opinions and tested on real patients having diagnosed higher level of stress and panic attacks/disorder.
 3. Comparing LoRa performance inside the palm plantation with other LPWAN technologies, such as the WiFi Halow.
3. The project's results will be copyrighted/patented with agreement from all members and sponsor.

Future Works:

1. Optimization of the hardware and software design for potential commercialization and **advocation into the TinyML** usage in healthcare while highlighting **Responsible AI**.
2. Further validation of the models with **clinical collaboration and on multi-centres** settings for evidence-based research.