[PJ2022-03] P2EI-WEALTH (Physiological and Psychological Edge Intelligence WEArable LoRa HealTH) System for Remote Indigenous Community and Disaster Recovery Operation

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)

P2EI-WEALTH (Physiological and Psychological Edge Intelligence WEArable LoRa HealTH) System for Remote Indigenous Community and Disaster Recovery Operation

Project Members :

Members	Instituition
Asma' Abu-Samah	UKM, Malaysia
Rosdiadee Nordin	~~UKM, Malaysia~~ Sunway University, Malaysia
Nor Fadzilah Abdullah	UKM, Malaysia
Mohd Radzi Ab Rahim	PPTC and UKM, Malaysia
Reginald J. M. Mercado	GTek Entreprise, Philippines
Xarxes C. Alejos	GTek Entreprise, 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)

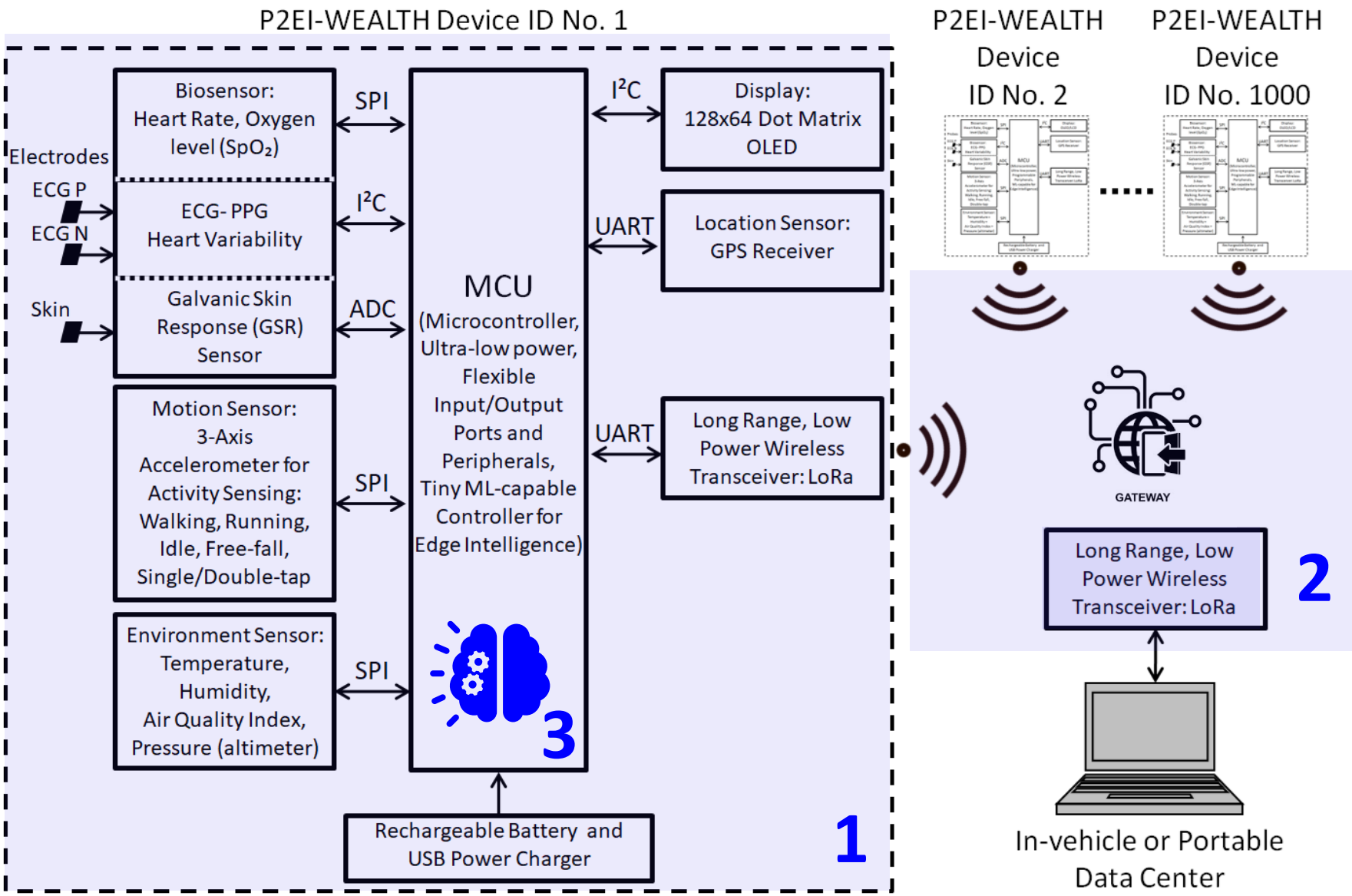
Project Budget (40,260 USD):
Closing expense 24,354 USD
**Expenses for Gtek Entreprise members covered by other grants*

Universiti Kebangsaan Malaysia — The National University of Malaysia
Gtek Enterprise
Mapúa University
NICT

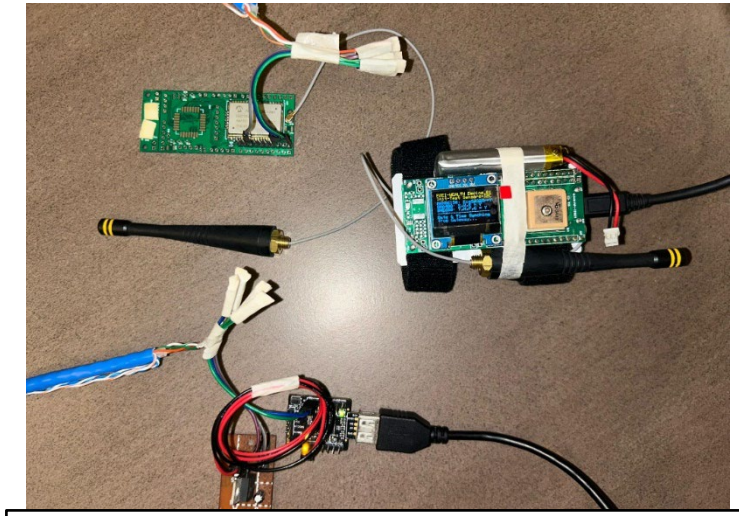
P2EI-WEALTH
(**P**hysiological and **P**sychological **E**dge **I**ntelligence **WEA**rable **L**oRa **H**ealTH) System

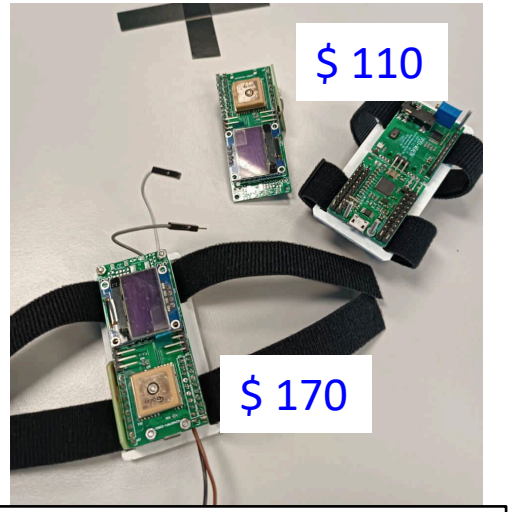
Overview of the proposed P2EI-WEALTH system & Research Activities

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



Project Activities and Results (1): Hardware Prototype Development





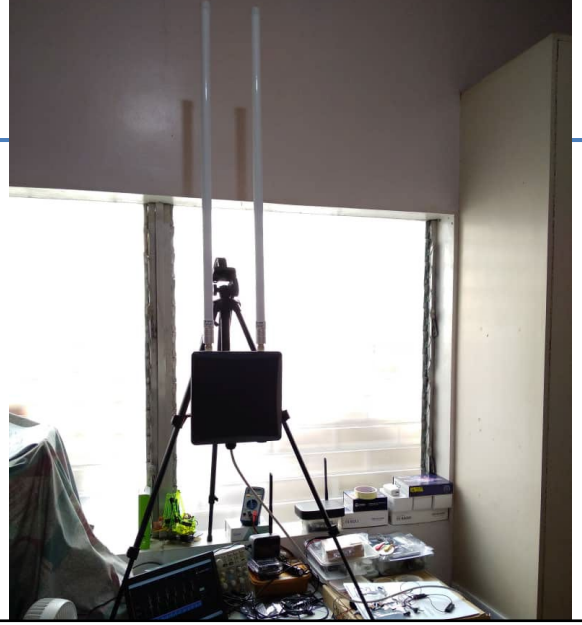
The P2P Devices (End-Nodes and the Gateway)

Manila visit to Mapua University and Gtek Entreprise

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

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

Project Activities and Results (1): Hardware Prototype Replication



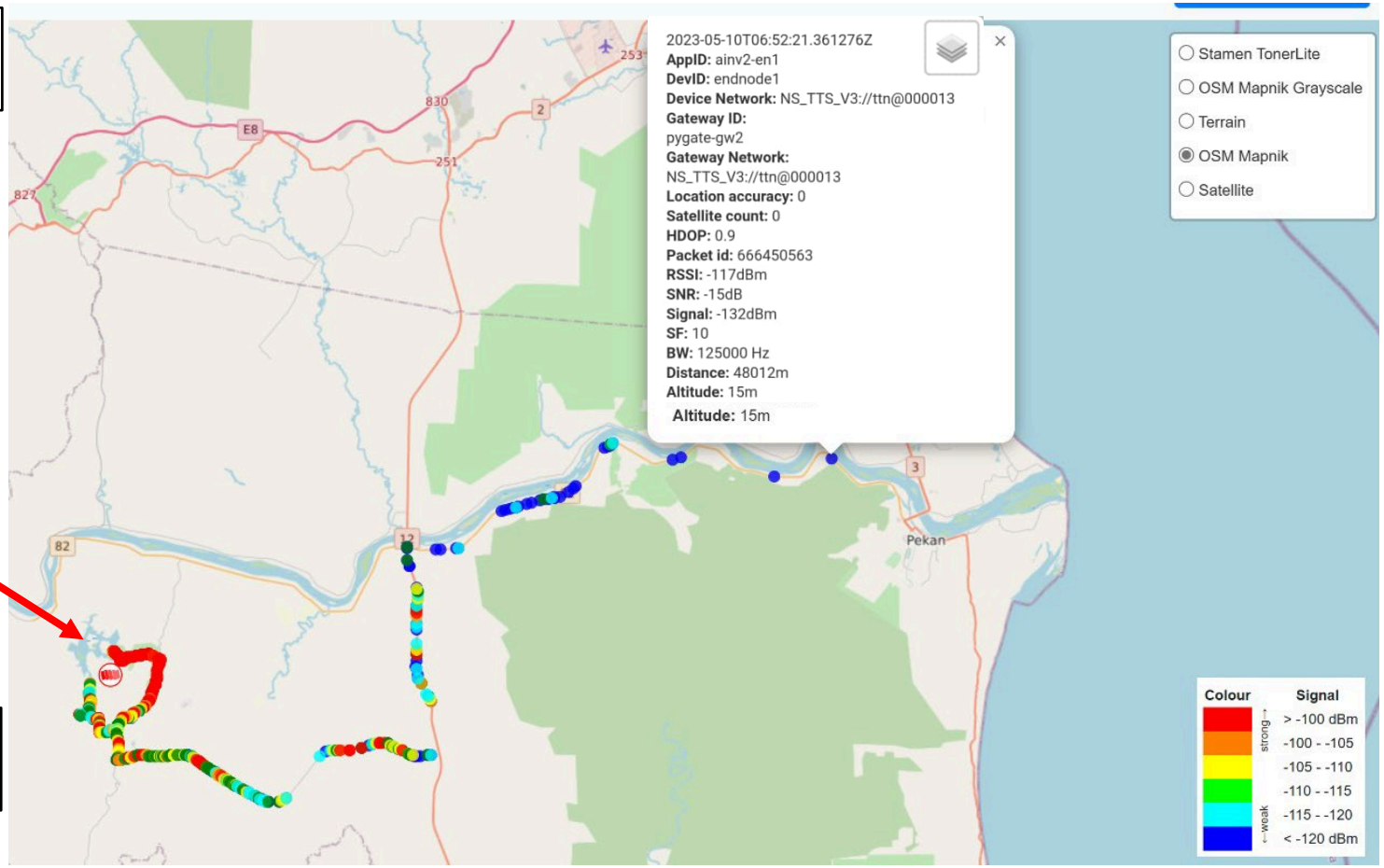
Workshop 1 (10th-12th July, 2023)

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

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

Project Activities and Results (2): Installation of Outdoor Gateway in Bukit Ketaya, Lake Chini

Installement of LoRa Gateway on identified point in Mount Ketaya at 208m ASL by Assof Prof. Dr. Nor Fadzilah



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

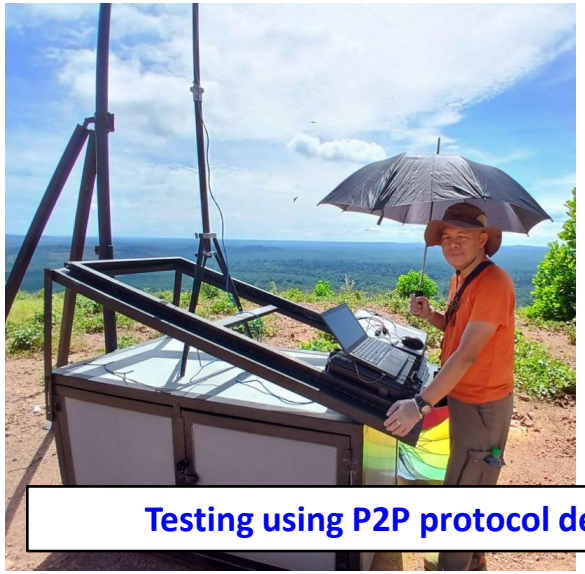
1 packet of 10 bytes
Furthest point reached at 48.012 km
Gateway: 8 dbi fiberglass, vertical polarized antenna
EN: 3 dbi antenna, Using Pycom-based EN with SF-10

Project Activities and Results (2): Measurement using the first prototypes in Lake Chini

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

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

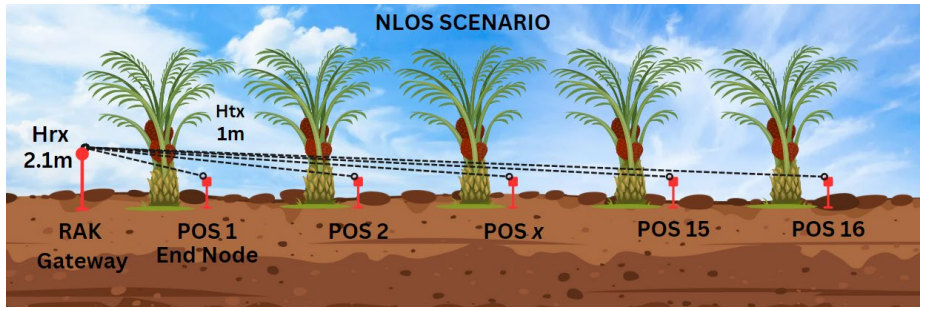
Mount of permanent structure for Bukit Ketaya by Prof. Rosdiadee

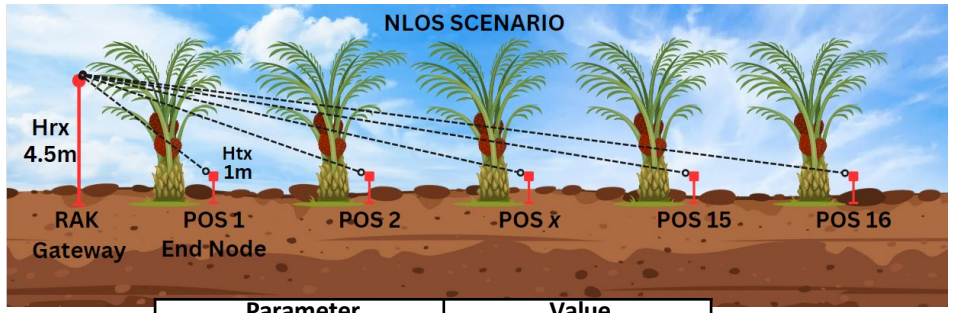


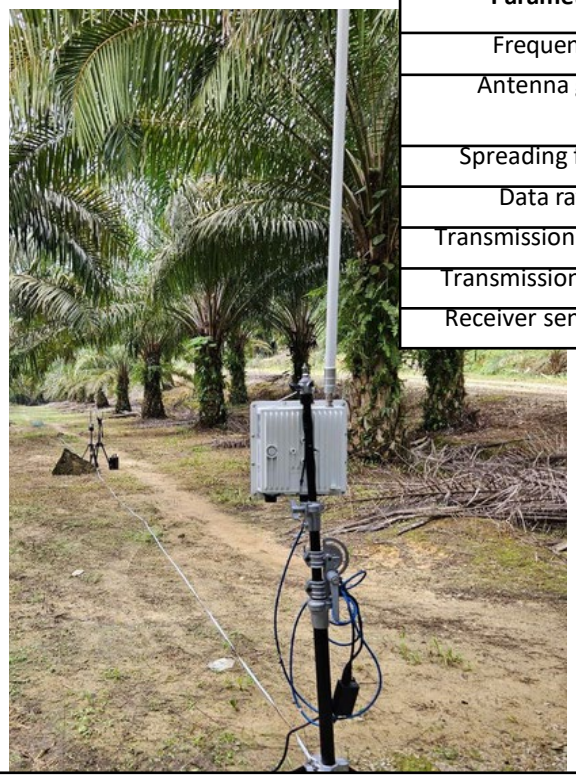
Testing using P2P protocol developed by Mr. Reggie (Gtek)

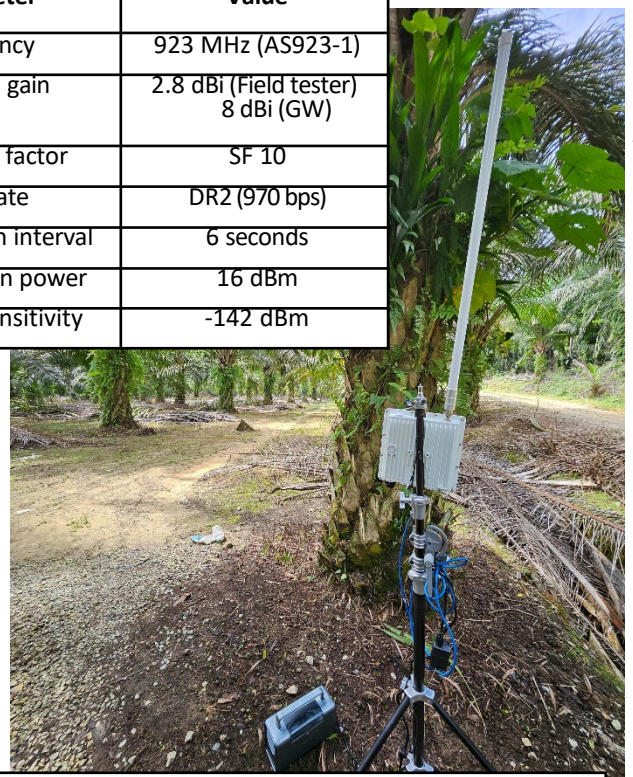
Project Activities and Results (2): Propagation Modeling for Palm Plantation

1. Palm plantation is one of the sources of economy for the Chini indigenous people
2. LoRa is being explored as WSN and IoT communication solution in the oil palm industry for diverse aspects including safety and risk of workers

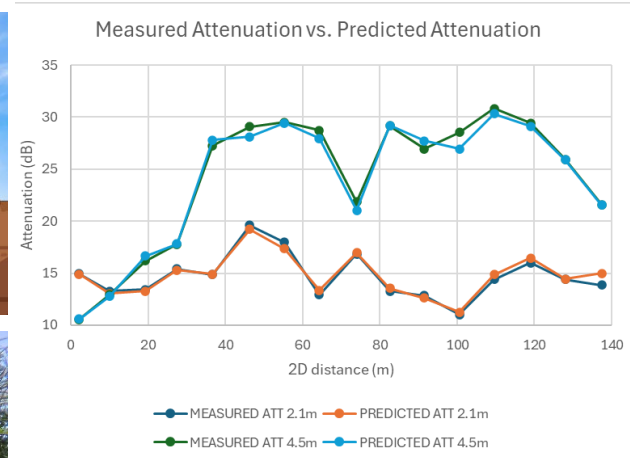








Parameter	Value
Frequency	923 MHz (AS923-1)
Antenna gain	2.8 dBi (Field tester) 8 dBi (GW)
Spreading factor	SF 10
Data rate	DR2 (970 bps)
Transmission interval	6 seconds
Transmission power	16 dBm
Receiver sensitivity	-142 dBm



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

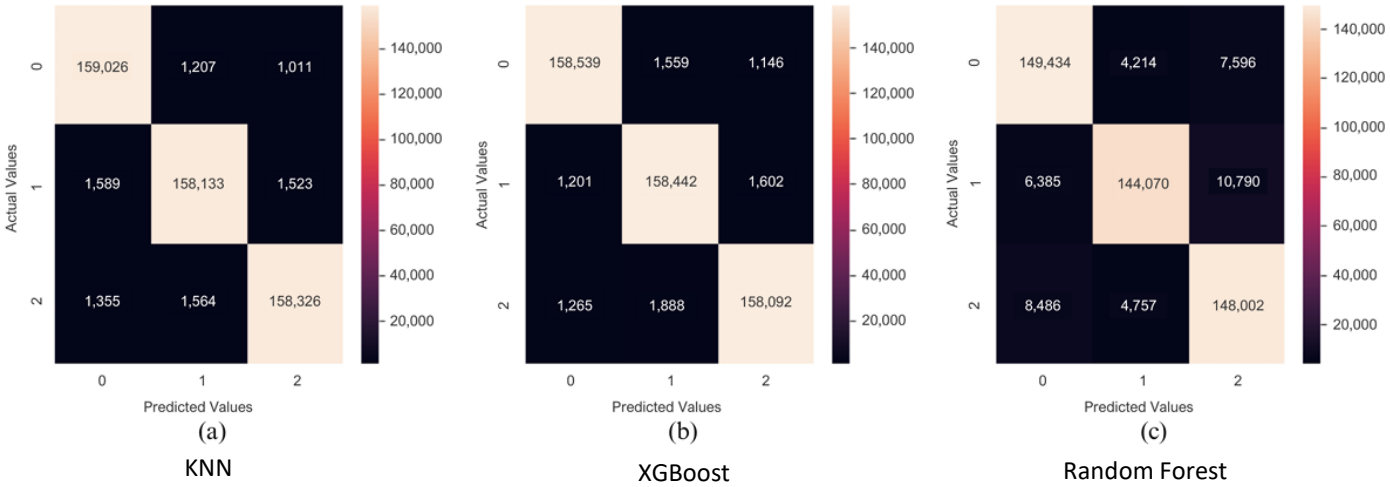
Measurement in the palm plantation using LOS and NLOS configurations (April-July 2024)

Machine learning-based propagation model development

Project Activities and Results (3): Prediction Models for Stress Detection

Evaluation results for Learning and Testing multiple algorithms using Nurses Dataset [1]

	Validation Set				Test Set			
Classifier	**Accuracy**	**Precision**	**Recall**	**F1-Score**	**Accuracy**	**Precision**	**Recall**	**F1-Score**
KNN	0.9831	0.9831	0.9831	0.9831	0.9829	0.9829	0.9829	0.9829
XGBoost	0.9823	0.9823	0.9823	0.9823	0.9821	0.9821	0.9821	0.9821
Random Forest	0.9125	0.9133	0.9125	0.9126	0.9128	0.9136	0.9128	0.9129
Decision Tree	0.8708	0.8710	0.8708	0.8709	0.8702	0.8704	0.8702	0.8703
LightGBM	0.8439	0.8444	0.8439	0.8440	0.8443	0.8448	0.8443	0.8444
Logistic Regression	0.4586	0.4595	0.4586	0.4575	0.4599	0.4609	0.4599	0.4588

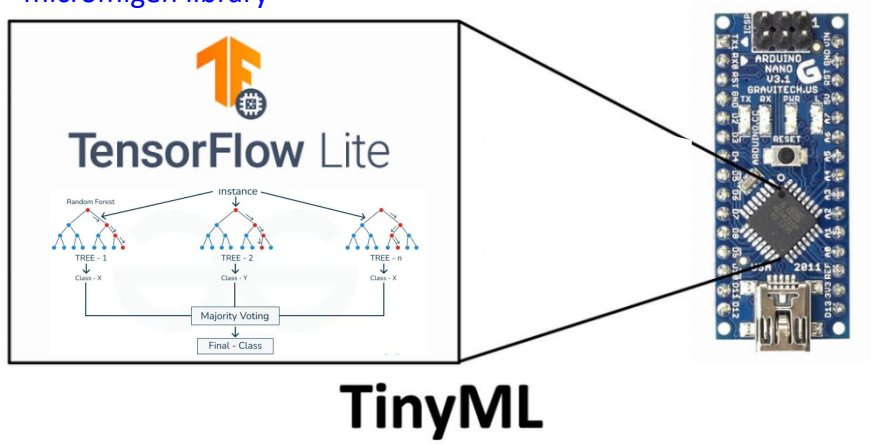


(a) KNN (b) XGBoost (c) Random Forest

[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.

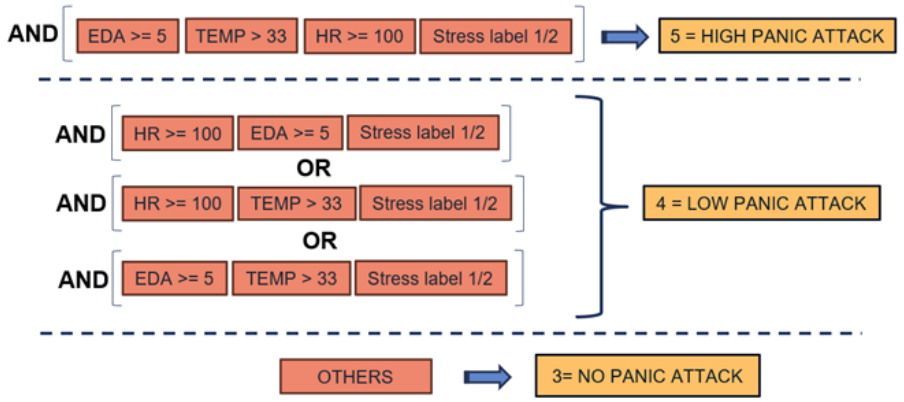
Deployment in P2EI-WEALTH

micromlgen library



XGBoost(1)	objective max_depth n_estimators	'multi:softmax' 15 100	98.2%	226 MB
XGBoost(2)	objective learning_rate max_depth n_estimators	'multi:softmax' 0.7 7 50	92.5%	4.47 MB
XGBoost(3)	objective learning_rate max_depth n_estimators	'multi:softmax' 0.7 5 50	86.0%	1.12 MB
Random Forest(1)	criterion max_depth n_estimators	'gini' 15 100	92.3%	213.7 MB
Random Forest(2)	criterion max_depth n_estimators	'entropy' 15 100	91.4%	241 MB
Random Forest(3)	criterion max_depth n_estimators	'entropy' 7 50	73.2%	1.5 MB

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 (943718)	Validation (10% of 12') Data (104857)	Testing (3 Selected) Data (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%

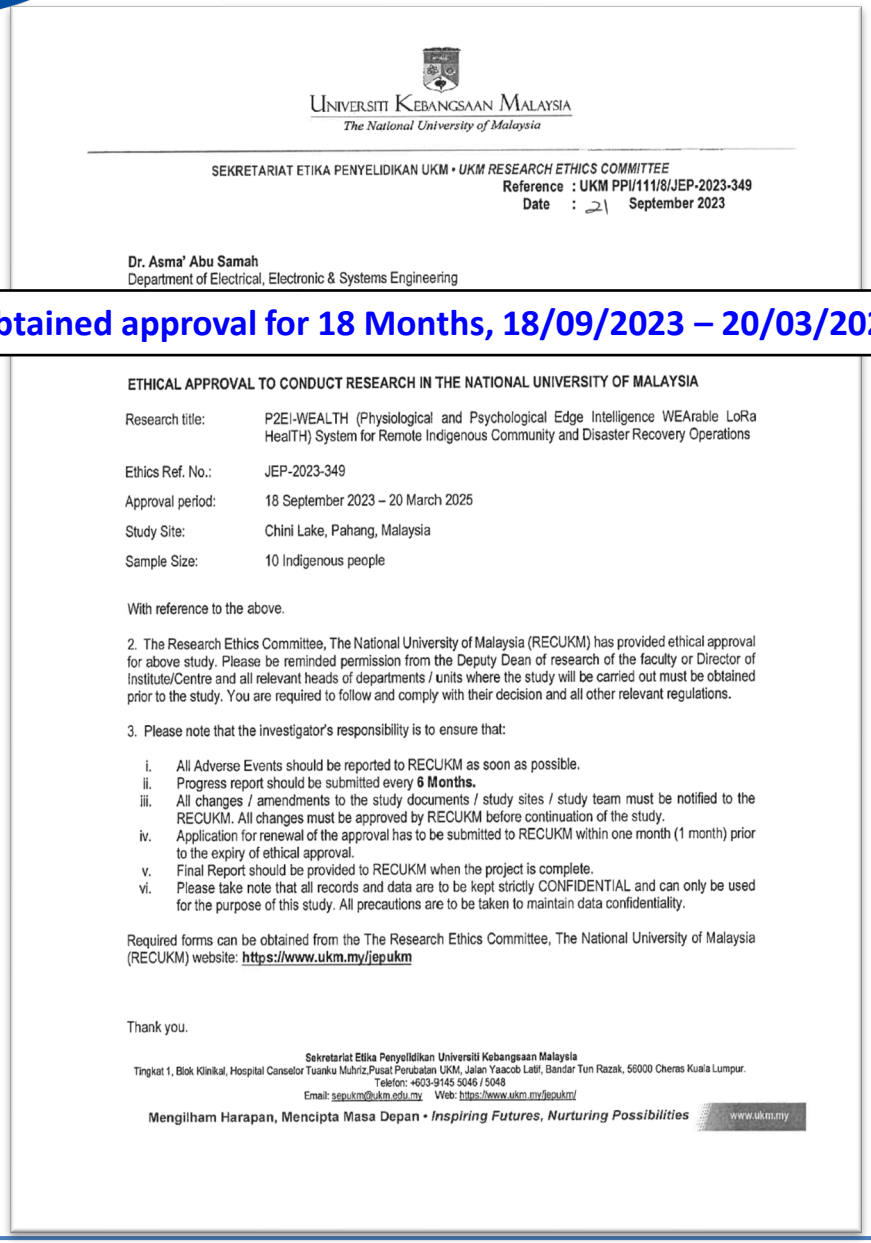
Evaluation results for multiple algorithms for Nurses Dataset [1]

Machine Learning Model	Accuracy and Respective Nurses Dataset		
	Training (Full 12' Nurses Data) (943718)	Training (Full 12' Nurses Data) (943718)	Testing (3 Selected Nurses Data) (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%

0.0003%

Project Activities and Results : Team meetings - Onlines, in MU (Nov 23) and in UKM (Jul 23, Aug 24)

Project Activities and Results : Ethical Approval, Dataset Collection and Future Collaboration



UNIVERSITI KEBANGSAAN MALAYSIA
The National University of Malaysia

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

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:

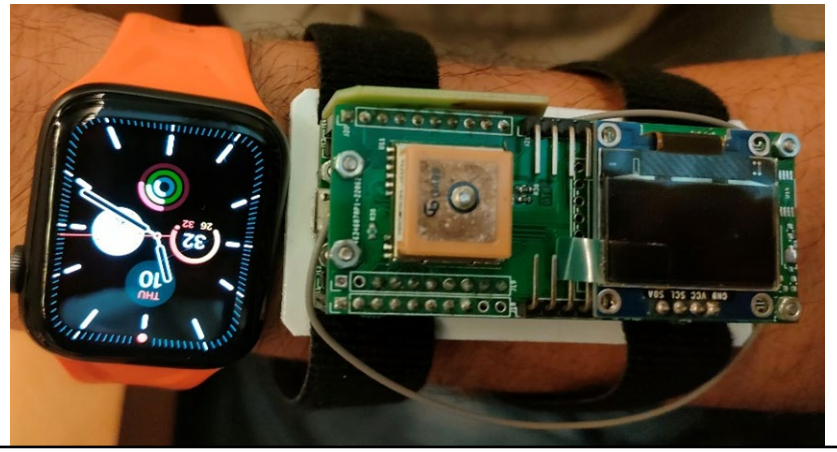
i. All Adverse Events should be reported to RECUKM as soon as possible.
ii. Progress report should be submitted every **6 Months.**
iii. All changes / amendments to the study documents / study sites / study team must be notified to the RECUKM. All changes must be approved by RECUKM before continuation 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 Klinikal, Hospital Canselor Tuanku Muhriz,Pusat Perubatan UKM, Jalan Yaacob Latif, Bandar Tun Razak, 56000 Cheras Kuala Lumpur.
Telefon: +603-9145 5046 / 5048
Email: sepukm@ukm.edu.my Web: https://www.ukm.my/jepukm/
Mengilham Harapan, Mencipta Masa Depan • ***Inspiring Futures, Nurturing Possibilities*** www.ukm.my

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



Validation tool

Data from P2EI-WEALTH and EMPATICA Embrace Plus will be shared in Open Platforms (Kaggle and Github)

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

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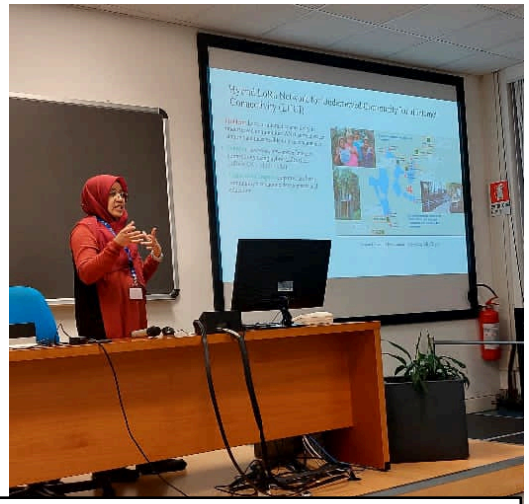
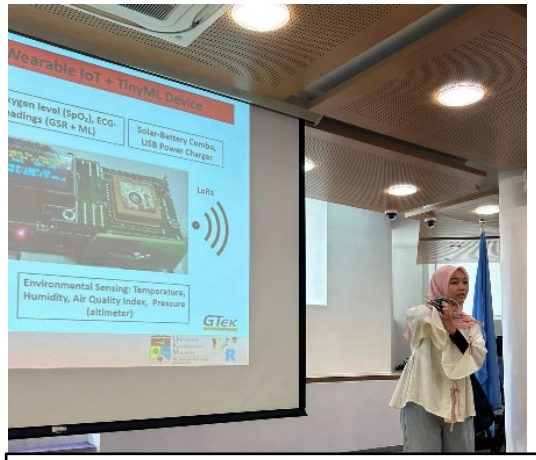
National University of Malaysia

Ongoing collaboration and securing grants with medical and biomedical UKM researchers to optimize the use of both devices

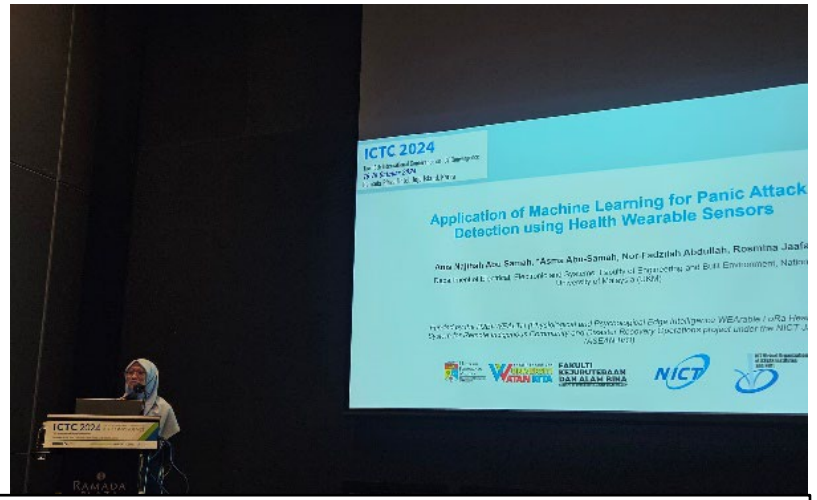
Project Activities and Results : Project Dissemination in Conferences and Workshops



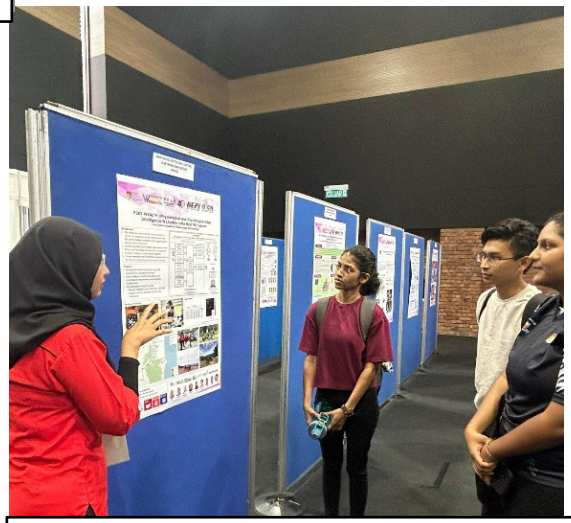
Workshop on Communication in Extreme Environments for Science and Sustainable Development, Nov 2023, Trieste, Italy



ICTP-UNU Workshop on TinyML for Sustainable Development, Apr 2024, Macau, China



International Conference on ICT Convergence (ICTC'24), Nov 2024, Jeju-do, South Korea



Research, Innovation & Commercialization Highlights (RICH'24), Oct 2024, UKM Malaysia

Scientific Contribution : Presentation at International Conferences and Publications

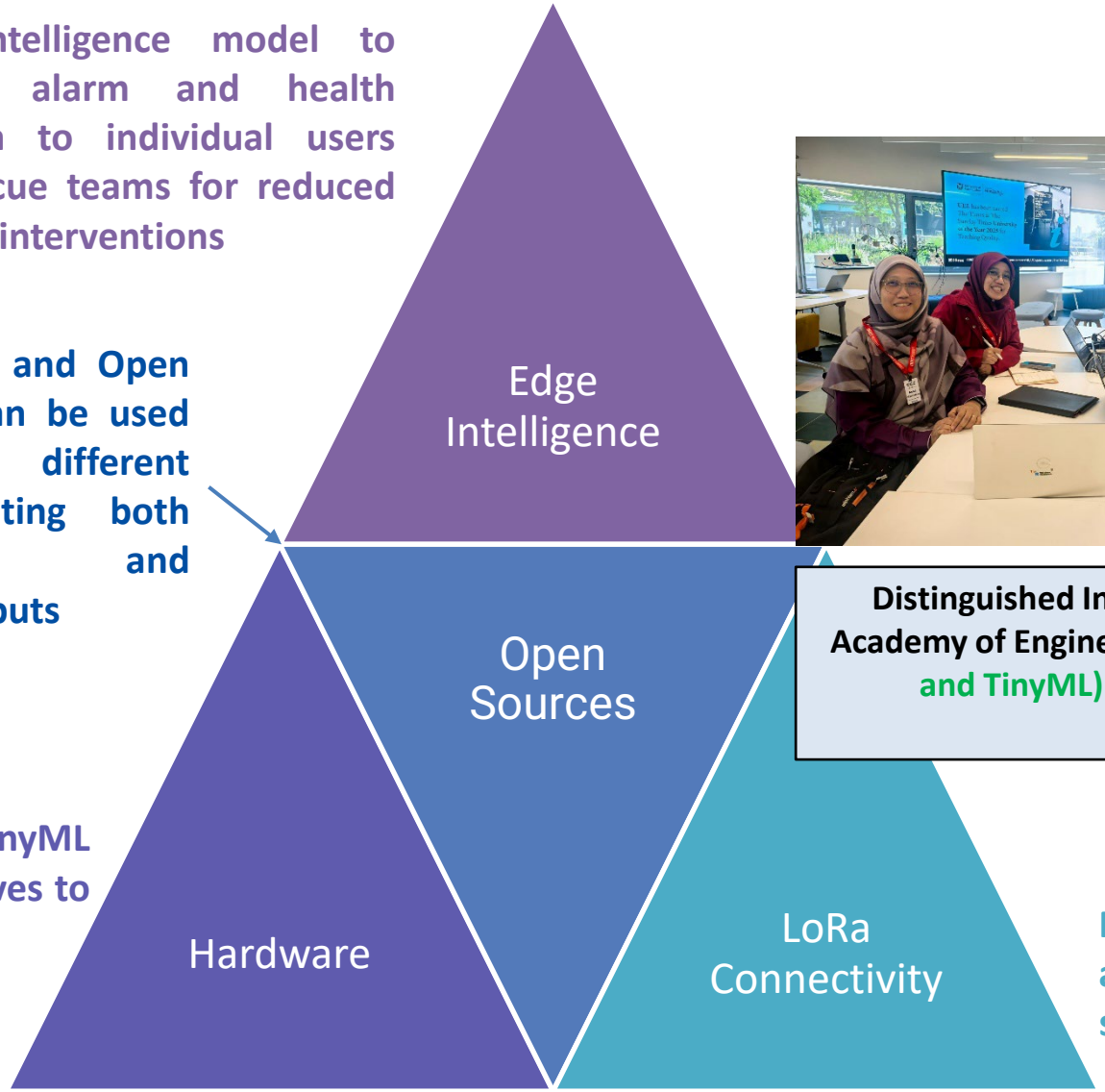
No:	Paper title:	Author names	Affiliation	Conference/Workshop/Journal name:	Conference date	Conference Venue
1.	Classification of stress using Machine Learning based on Physiological and Psychological Data from Wearables	Asma Abu-Samah, Jennifer Dela Cruz, Tuan Muhamad Affiq Aimullah Tuan Mohd Pauzi, 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 15th 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 15th International Conference on ICT Convergence	October 16-18, 2024	Jeju, Korea
6.	Deployment of TinyML-Based Stress Classification Using Computational Constrained Health Wearable	Asma Abu-Samah, Dalilah Ghaffa, Nor Fadzilah Abdullah, Noorfazila Kamal, Rosdiadee Nordin, Jennifer C Dela Cruz, Glenn V Magwili, Reginald Juan Mercado	UKM, MU, G-Tek	MDPI Electronics, WOS Q2 (Published Feb 10, 2025)		
7.	Cutting AI down to size	By Sandeep Ravindran	US-based Science Journalist	Science Magazine, Vol 387, Issue 6736 (Published Feb 20, 2025)		

Societal Impacts : A future in the making

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

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

Expansion of TinyML Network initiatives to other use-cases



Distinguished International Associates (DIA Round 5) Awardee under the Royal Academy of Engineering UK on The H.E.A.R.T (Health, Engineering, AI, Responsibility and TinyML) Project. Collaboration with University of East London (UEL), Mar 2025 – Feb 2026.

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

Conclusion and Future Works

Conclusion:

1. The project has 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.