TV White Space (TVWS) Experimental for Application in Remote Area

Hafizal Mohamad (MIMOS Berhad, Malaysia)

IVO Forum @ Brunei
24th November 2017

Team Members

- NICT, Japan
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  - Dr. Fumihide Kojima
  - Hoang Vinh Dien, Hirokazu Sawada, Nobuyuki Asai
- MIMOS, Malaysia
  - Ir. Dr. Hafizal Mohamad
  - Ir. Dr. Nordin Ramli
- University Kebangsaan Malaysia (UKM)
  - Assoc. Prof. Ir. Dr. Rosdiadee Nordin
  - Prof. Dr. Mahamod Ismail
- University of San Carlos, Philippines
  - Alberto S. Bañacia
  - Antonio Montejo III
- Support:
  - **MIMOS**: Azrulmukmin Azmi, Ahmad Zaki Abu Bakar, Azmi Yaacob
  - **UKM**: Prof. Dato' Dr. Mushrifah Idris, Assoc. Prof. Dr. Shanudin Zakaria, Dr. Khairl Azmi Abu Bakar, Dr. Mehran Behjati, Dr. Anabi Hilary Kelechi

Presentation Outline

- Background
- Project Implementation Schedule
  - Chini Lake, Malaysia
  - USC and Surigao, Philippines
- Project Highlight (2017)
  - WiSUN and LoRa (sub-GHz) Experiment at Chini Lake for Hydrological Monitoring Application
    Surigao: Philippines Experiment for Emergency Communications using TV White Space (IEEE 802.11af)
- Summary

Background

Project Overview

- Project title:
  - TV White Space (TVWS) Experimental for Application in Remote Area
- Project theme:
  - Social Renovation in Rural Areas and/or Urban Areas
  - **To develop solution for hydrological quality monitoring in rural area and emergency network in urban area**
- Project members:
  - NICT, Japan
  - MIMOS & UKM, Malaysia
  - University of San Carlos, Philippines
- Amount:
  - USD 29,900
- Duration:
  - 21 months (Jul 2016 – Mar 2018)

Project Impacts

- This project enables connectivity for multiple sensors in rural area
- Two potential experimental sites have been identified with the following benefits;
  - as hydrological monitoring system to avoid **Chini Lake (Malaysia)**
  - as emergency wireless networking at **Surigao (Philippines)**
- These applications are very critical for natural disaster management
- These applications are useful for people in rural areas as their daily life will be affected by any problem related to environmental pollution and natural disaster
- The implemented system provides ICT solutions to protect the environment and saves human lives

Recap: Progress & Achievement *(Jul 2016 – Nov 2016)*

- Discussion with regulator and stakeholders
- Specific experimental sites for installation identified
- TVWS equipment by NICT are ready
- CRA signed by NICT, MIMOS and USC
- Radio propagation study conducted at Chini and USC
- Spectrum measurement conducted at Chini
- Face-to-face meeting in Nov 2016

Project Implementation Schedule

Project Schedule (Malaysia)

Activities	2016						2017											2018		
	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M
Discussion with regulator and stakeholders	X	X	X	X	X	X	X	X													
Site visit and experimental work at Chini Lake	X			X		X			X			X		X				X		X	
Theoretical study and path loss simulation	X	X	X	X																	
Conduct TVWS spectrum measurement					X	X	X	X													
WiSUN equipment transfer from NICT									X	X	X										
WiSUN and LoRa installation and experiment at Chini Lake												X	X	X							
Prepare and present research findings															X	X	X				
Further data collection and analysis																		X	X	X	
End of project report																					X
Face-to-face meeting and discussion					X				X			X						X			

Project Schedule (Philippines)

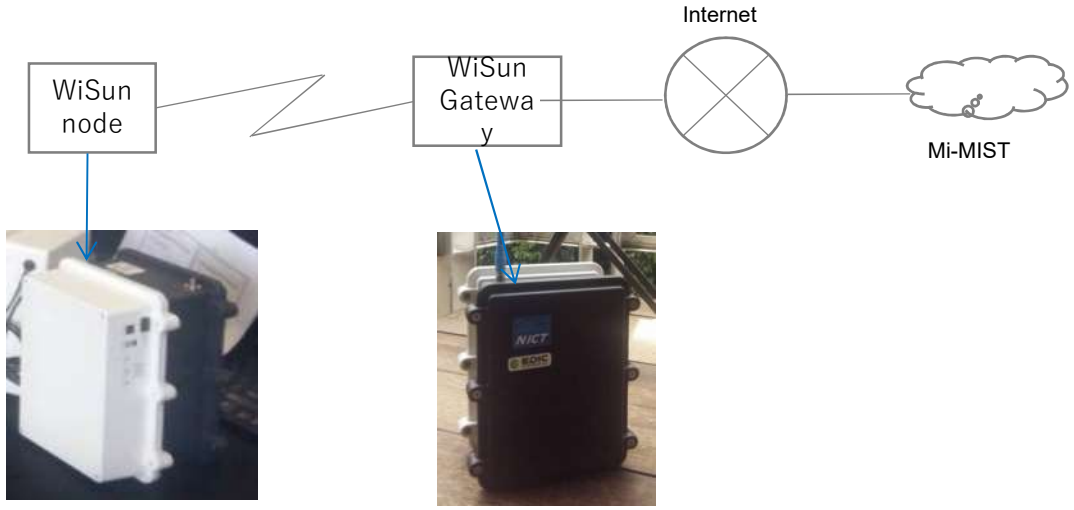
Project Activities	2016						2017											2018			
	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M
Topographical profiling of USC Talamban and site visit to Bogo	X	X	X																		
TVWS license application (NTC)			X	X	X																
MOA with DICT-Cebu on TVWS					X	X	X														
Transfer and arrival of NICT TVWS equipment to USC						X	X														
Experimental work for NICT IEEE 802.11af devices for fixed location							X	X	X												
Multihop deployment of NICT IEEE 802.11af in USC Talamban									X	X	X										
Procurement, installation and integration of equipment											X	X									
Experimental work for NICT IEEE 802.11af for multi-floored												X	X	X							
TVWS deployment for disaster response at Surigao														X	X	X	X				
Publish research findings and end of project report																		X	X	X	X

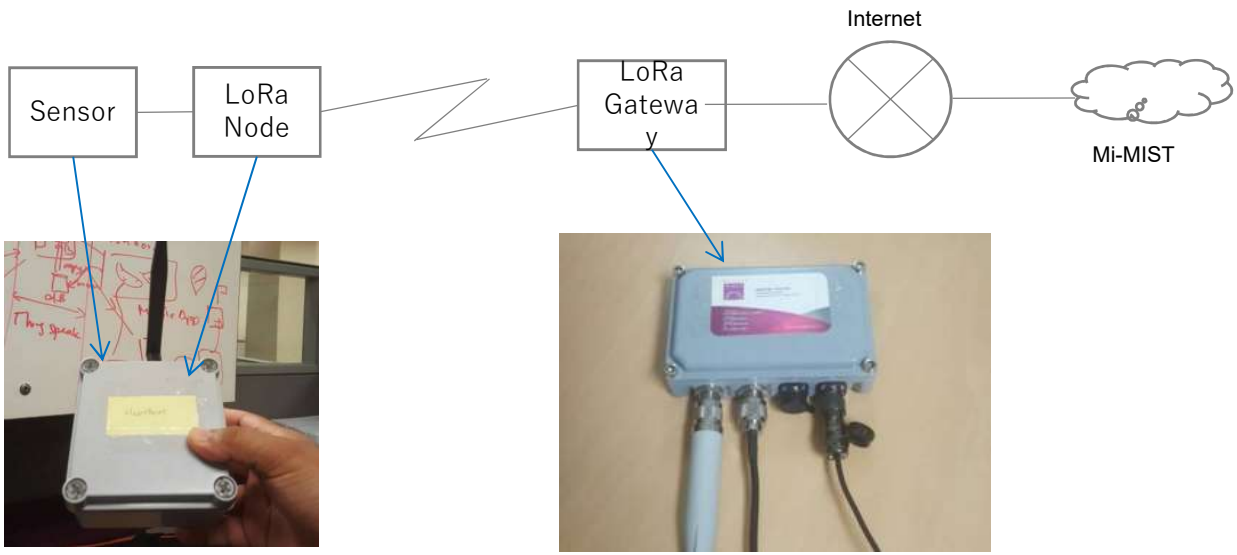
F2F Meeting in March 2017 *(Discussion & Site Visit to Chini Lake)*

WiSUN and LoRa (sub-GHz) Experiment at Chini Lake for Hydrological Monitoring Application

NICT, Japan: Kentaro Ishizu and Hoang Vinh Dien
MIMOS: Hafizal Mohamad and Nordin Ramli, Azrulmukmin Azmi
Ahmad Zaki Abu Bakar
UKM: Rosdiadee Nordin and Mahamod Ismail

WiSUN and LoRa Setup



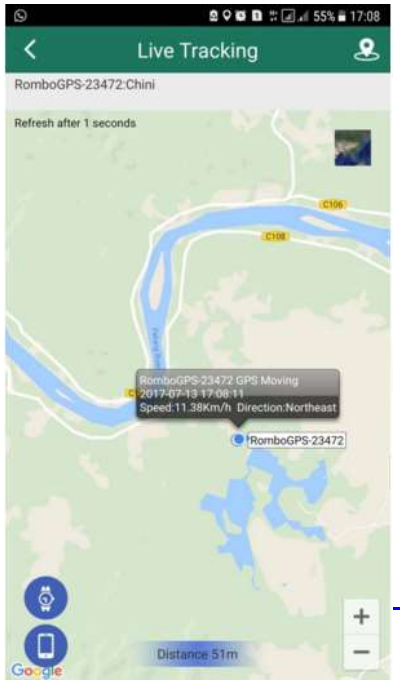


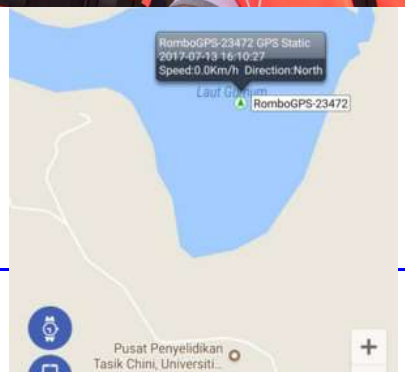
WiSUN Multihop Setup

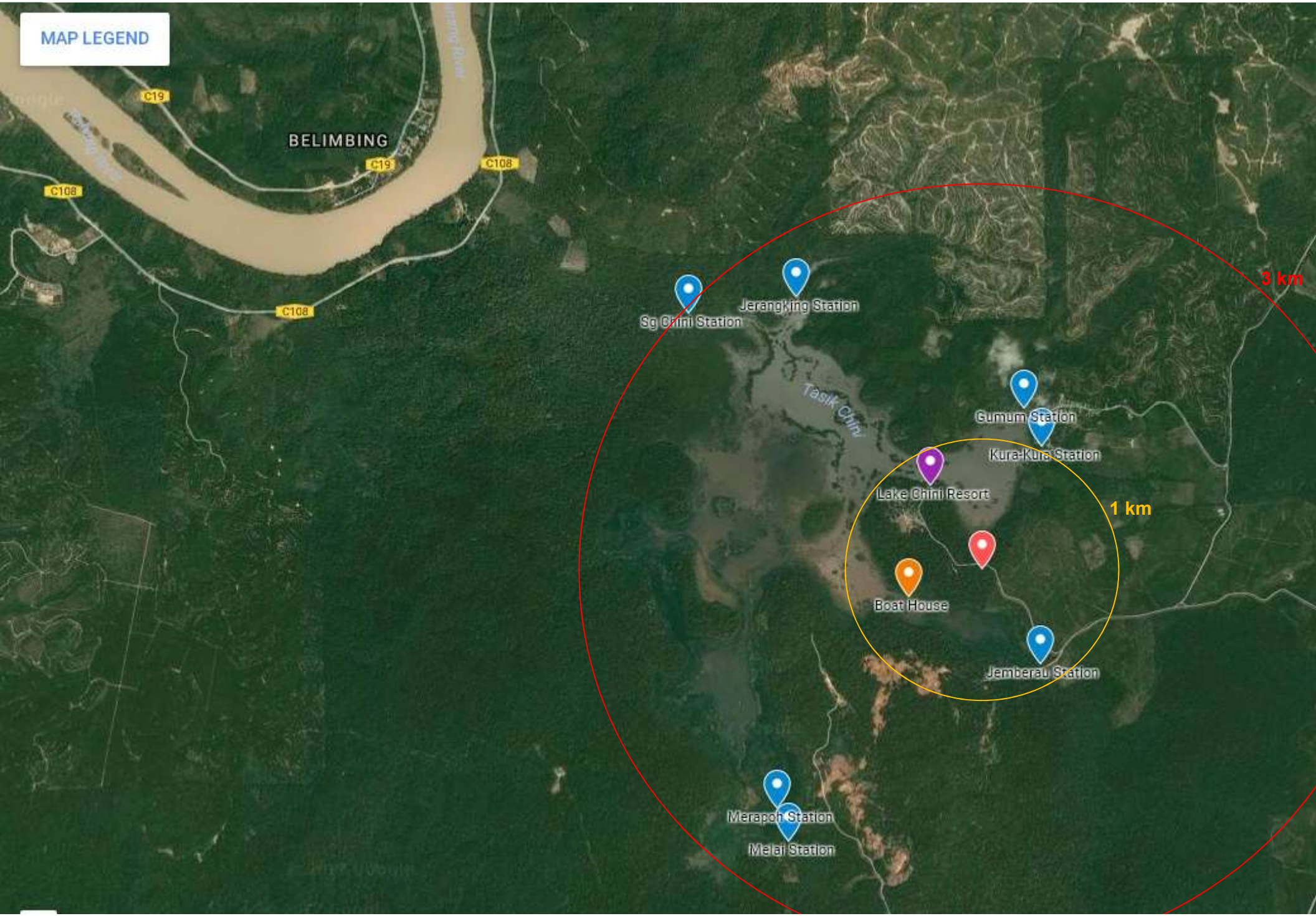
Set no	Location	Note
1	BS at Research Centre, UE1 at Jemberau station	1 hop experiment, on land
2	BS at Research Centre, UE1 on the boat (position of the boat is 500m from BS, toward the Kura-Kura Stn)	1 hop experiment, on water
3	BS and UE1 as in set 2, UE2 at Kura-Kura Station	2 hop experiment, on water
4	BS and UE1 as in set 2, UE2 at Gumum Station	2 hop experiment, further distance
4.1	BS, UE1, UE2 as in set 3, UE3 at Gumum Station	3 hop experiment, if Set 4 is not working
5	Other experiment to cover Merapoh/Melai Station	3 hop experiment, further distance
6	Other experiment to cover Jerangking/Sg Chini station	3 hop experiment, cover all stations

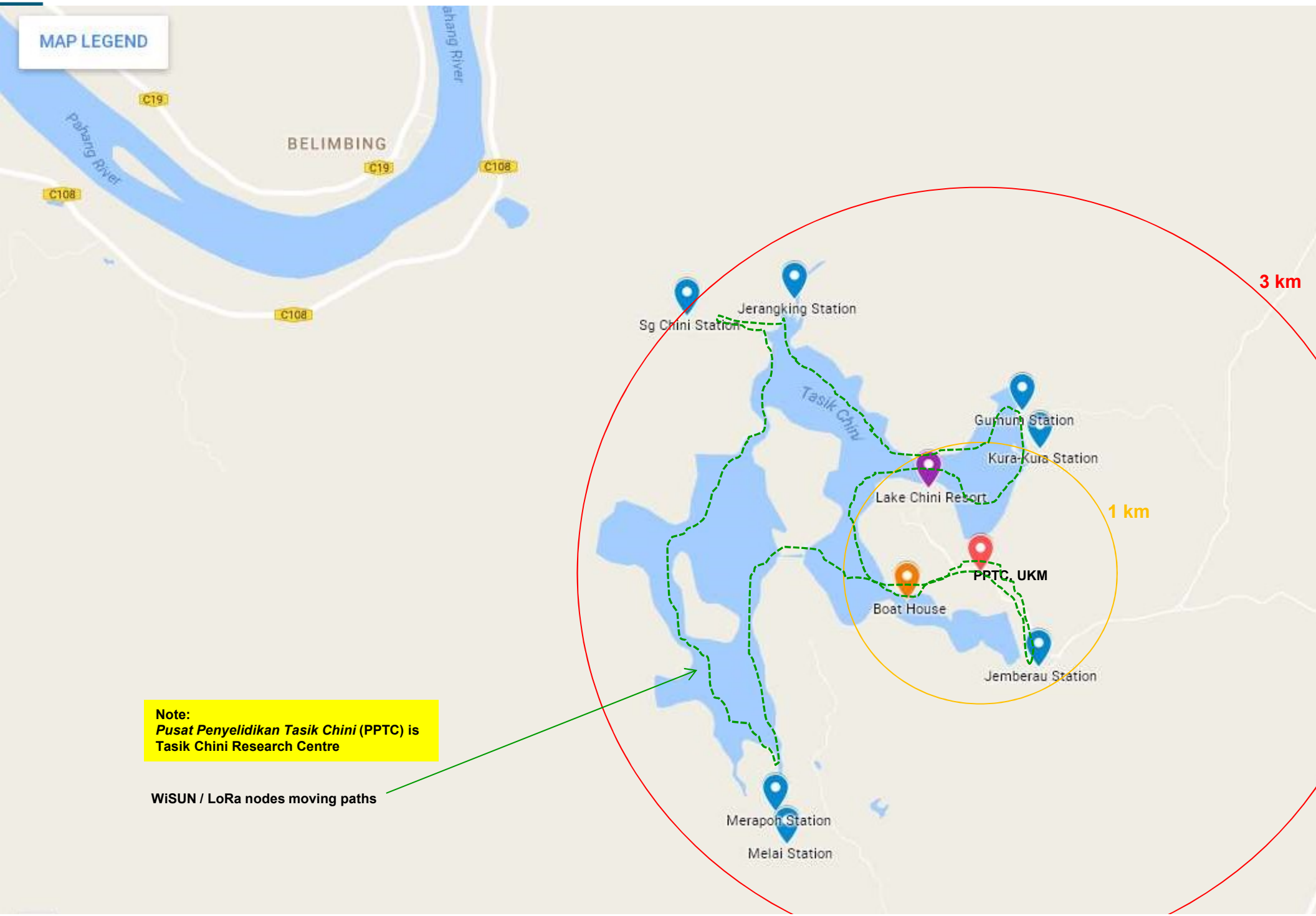
WiSUN and LoRa Gateway at Control Centre (PPTC)

WiSUN/LoRa Nodes – *move around lake & water station*

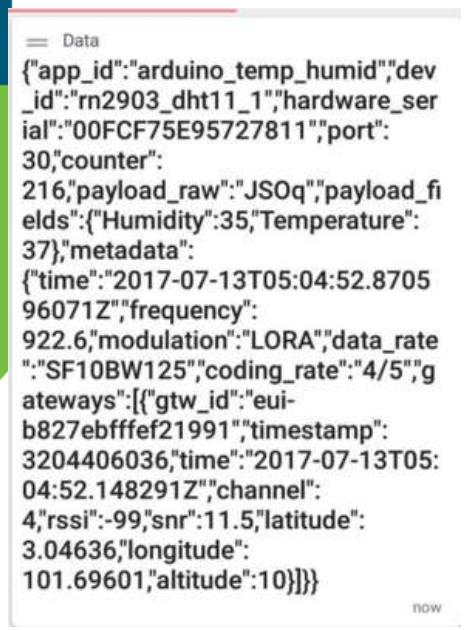


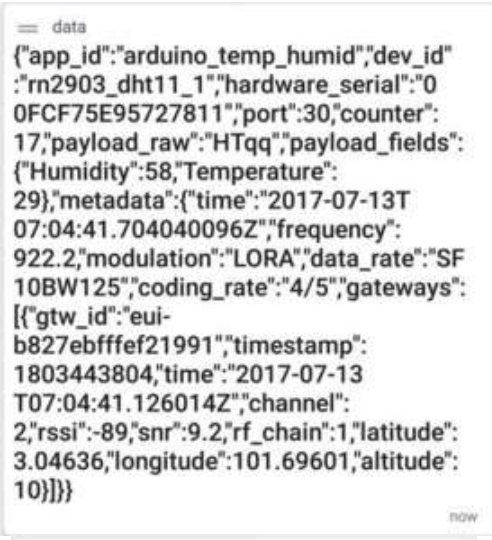


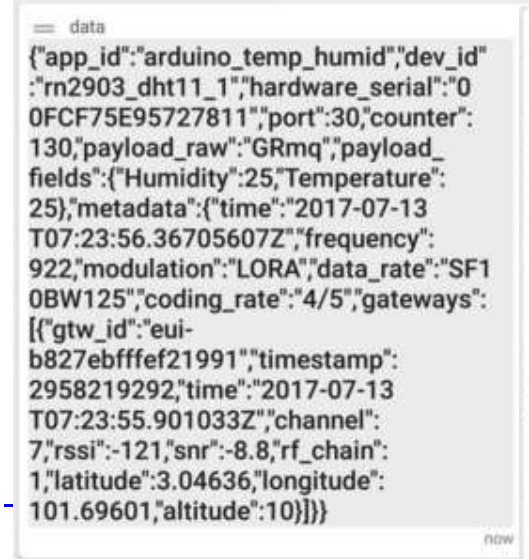

MAP LEGEND
BELIMBING
C19
C108
3 km
1 km
Sg Chini Station
Jerangking Station
Tasik Chini
Gumum Station
Kura-Kura Station
Lake Chini Resort
Boat House
Jemberau Station
Merapoh Station
Melai Station


MAP LEGEND
C19
C108
BELIMBING
Pahang River
Sg Chini Station
Jerangking Station
Tasik Chini
Gumum Station
Kura-Kura Station
Lake Chini Resort
PPTC, UKM
Boat House
Jemberau Station
Merapoh Station
Melai Station
3 km
1 km
Note:
Pusat Penyelidikan Tasik Chini (PPTC) is
Tasik Chini Research Centre
WiSUN / LoRa nodes moving paths

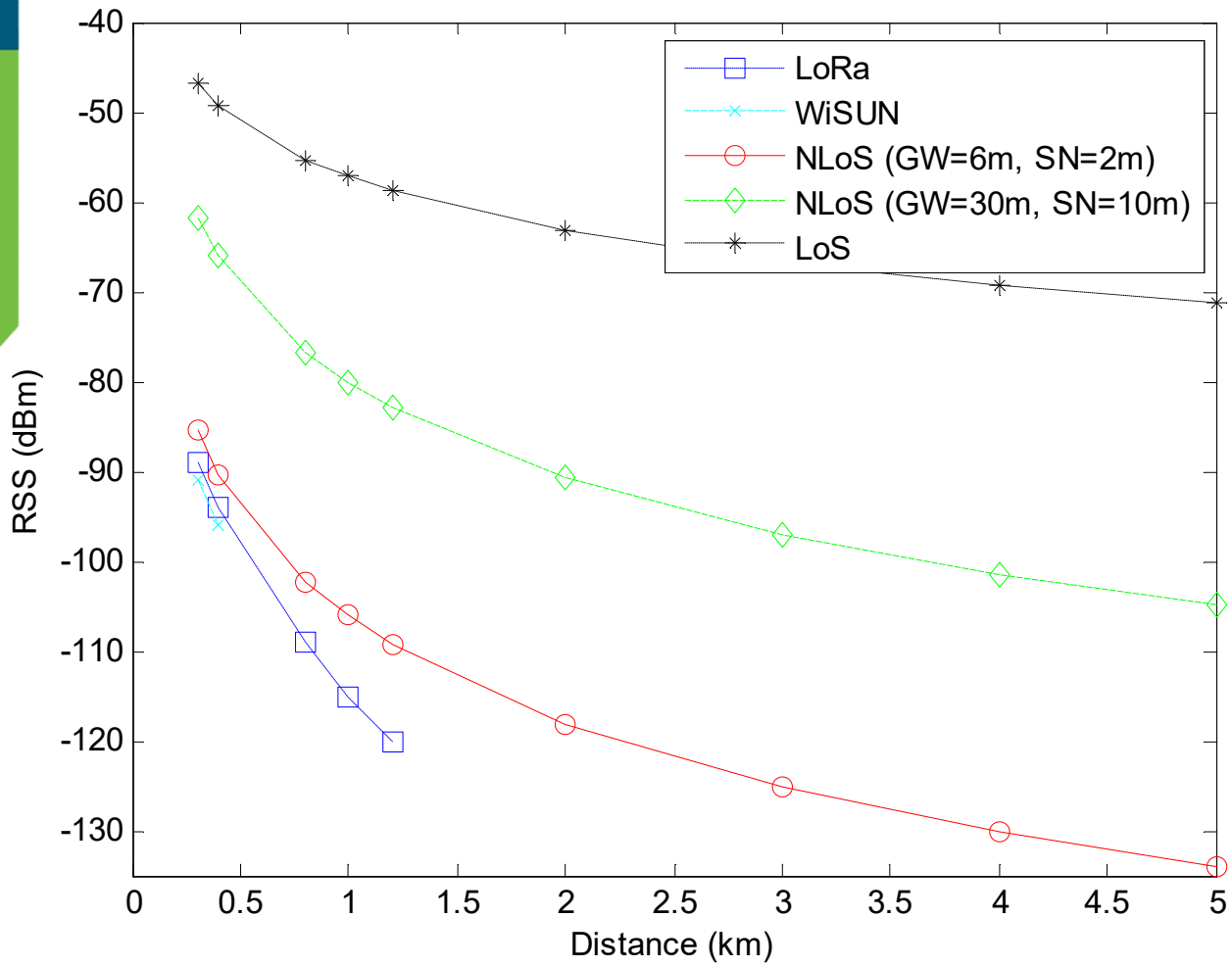
Snapshot of transmitted data and RSSI







WiSUN/LoRa and Friis/Hata Models



RSS at different Tx-Rx separation distance based on LoS/NLoS models in comparison with actual WiSUN/LoRa implementation

The Friis LoS model represents an ideal propagation condition, whereby there is no obstruction between the node and gateway. NLoS model based on Hata model is plotted for different transmitter (SN) and receiver (GW) height. From our WiSUN/LoRa implementation work, it is observed that the actual measurement around Tasik Chini is worse than NLoS Hata model for GW = 6m & SN = 2m.

Green diamond markers and red square markers represent the simulated configuration for GW = 30m & SN = 10m, and GW = 6m & SN = 2m, respectively. From the simulated results, the signal propagates better for high transmitter and receiver placements, whereby an improvement of around 25dBm could be achieved if the GW height is increased from 6m to 30m, while the SN height is increased from 2m to 10m.

Results and Findings

- WiSUN and LoRa gateways were installed at PPTC (refer photo)
- Field study and RSSI evaluation
  - Signal could reach Gumum (1.3km), Kura-kura (1.1km), Jemberau (0.8km) stations
  - Signal could not reach Sg Chini (3km), Melai (2.5km) and other water stations due to challenging propagation environment
  - Comparison of LOS/NLOS model and measurement is shown in previous slide. Height of the gateway and antenna gain are important for ubiquitous coverage around the lake
- Sensor nodes and WiSUN/LoRa gateway operates successfully within the stipulated regulation guidelines and we manage to setup a private WiSUN/LoRa network. WiSUN/LoRa nodes transmit sensor data every 10 seconds.

Surigao: Philippines Experiment for Emergency Communications using TV White Space (IEEE 802.11af)

Alberto S. Bañacia and Antonio Montejo III
Department of Electrical & Electronics Engineering, University of San Carlos, Cebu City, Philippines

Overview: TVWS implementation

- Objective:
  - To perform tests and measurements that will demonstrate the capability of TVWS technology (IEEE 802.22af) to provide internet connectivity to remote area and as an emergency network during disasters
- Project Site:
  - Bgy. Diaz Elementary School and other premises of San Francisco, Surigao del Norte

Use Case #1: Point to Multipoint

Topography of the Point-to-Multipoint Network

Elevation Profile between the AP (Brgy. Hall) to STA1 (Principal's Office)

Use Case #1: Point to Multipoint

ACCESS POINT at BGY HALL

STATIONS 1 and 2 at the
Diaz Elementary School

Use Case #1: PtMP Throughput Performance

Station 1: Principal's Office				
Antenna: 3-element				
Tx Power (dBm)	MCS	RSSI (dBm)	Downlink (Mbps)	Uplink (Mbps)
20	0	-87	1.46	1.27
15	0	-92	0	0
20	3	-89	3.43	3.38
15	3	-91	0	0
20	5	-87	0	0
Station 2: Computer Room				
Antenna: 3-element				
Tx Power (dBm)	MCS	RSSI (dBm)	Downlink (dBm)	Uplink (dBm)
20	0	-88	1.22	0.764
15	0	-91	0	0
20	3	-89	3.56	0.235
15	3	-91	0	0
20	5	-89	0	0

Use Case #1: PtMP Application

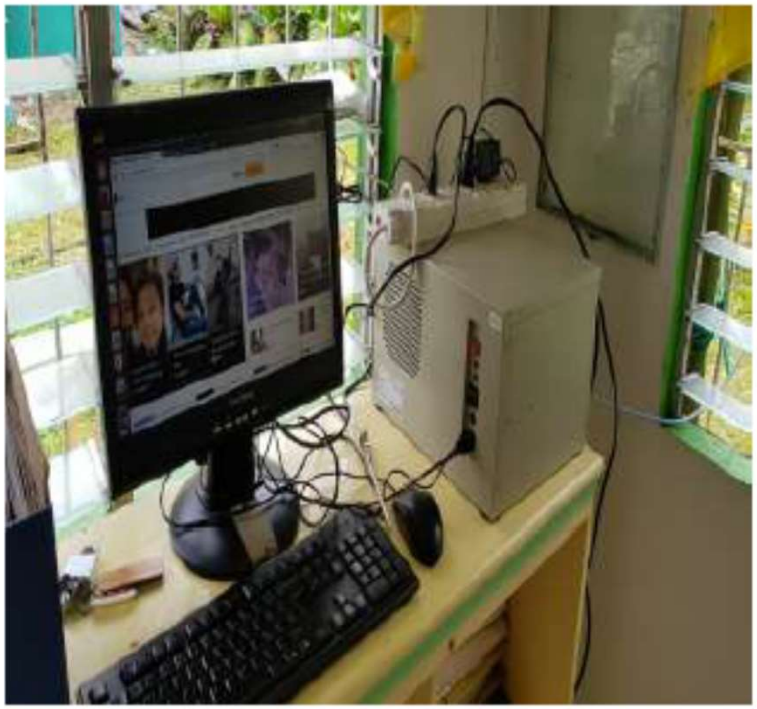
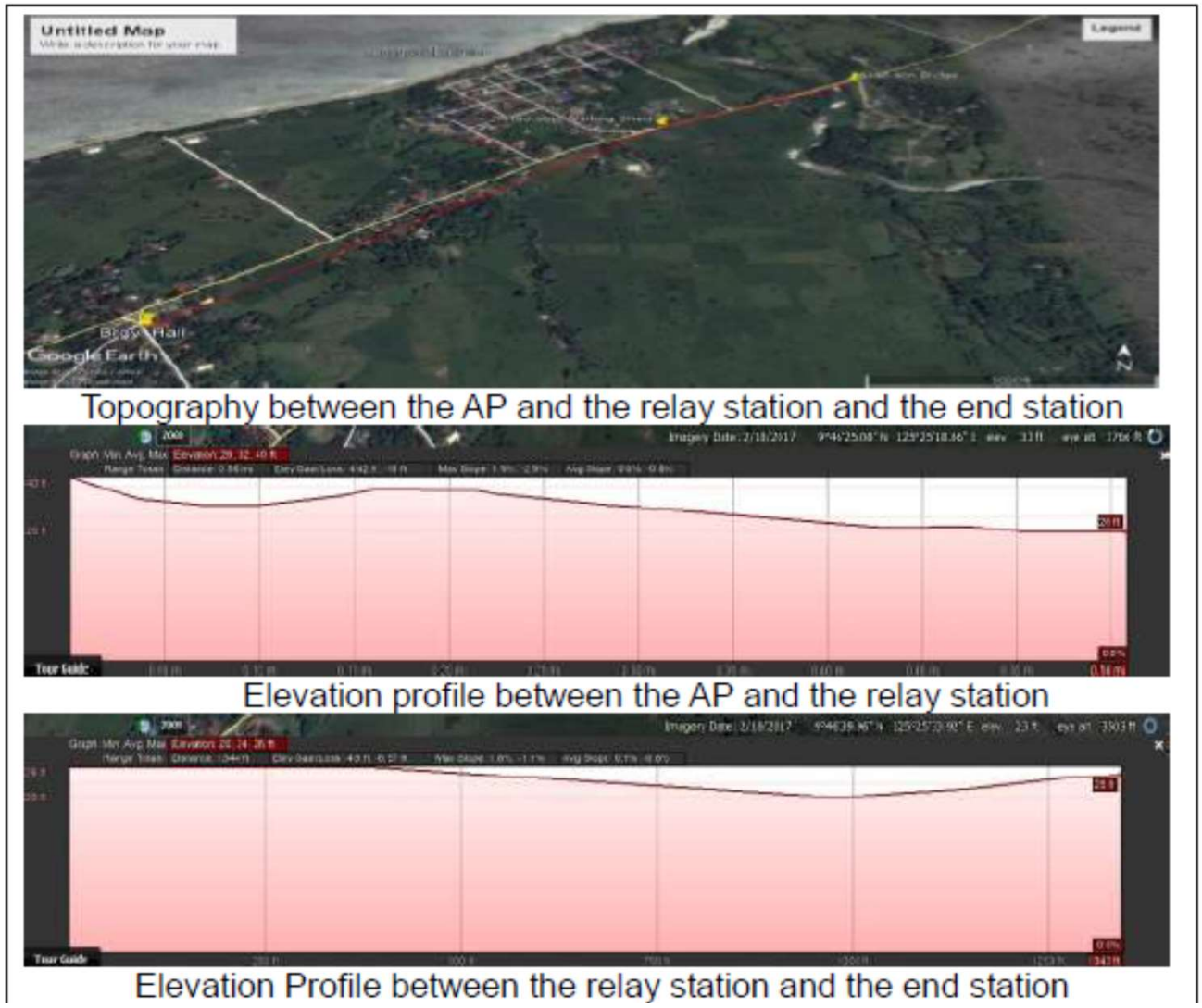


Figure Showing connectivity between AP (Bgy. Hall) and STA1 (Principal's Office)

Figure 6. Learning with the aid of internet connectivity

Use Case #2: Multihop TVWS



Use Case #2: Multihop TVWS

Use Case #2: Multihop Throughput Performance

Tx Power (dBm)	MCS	Hop 1(~800m from AP)			Hop 2(~400m from Relay Station)			Total Downlink (Mbps)	Total Uplink (Mbps)
		RSSI (dBm)	Downlink (Mbps)	Uplink (Mbps)	RSSI (dBm)	Downlink (Mbps)	Uplink (Mbps)		
20	0	-86	1.36	1.31	-72	1.41	1.36	1.36	1.31
20	3	-86	3.25	3.16	-72	3.66	3.55	3.25	3.16
20	5	-86	1.07	0	-72	4.92	4.61	1.07	0
15	0	-89	1.21	0.706	-76	1.39	1.35	1.21	0.706
15	3	-89	2.89	0.376	-76	3.6	3.36	2.89	0.376
15	5	-89	0	0	-77	0.47	0.423	0	0
10	0	-93	0.095	0.118	-85	1.43	1.32	0.095	0.118
10	3	-93	0	0	-85	3.5	3.55	0	0
10	5	no connection			-85	2.69	1.41	0	0
5	0	no connection			-88	1.36	0.811	0	0
5	3	no connection			-88	3.46	1.92	0	0
5	5	no connection			-89	0	0	0	0
0	0	no connection			-91	0.388	0.106	0	0
0	3	no connection			-92	0.188	0	0	0
0	5	no connection			-92	0	0	0	0

Findings: 802.11af (TVWS)

- Internet connection can be established between an access point and multi-points or stations in a remote area utilizing TVWS technology
  - Maximum throughput of 3.43 Mbps (downlink) and 3.38 Mbps (uplink) at a maximum power of 20 dBm with MCS 3
- In the case of point to multipoint network, utilizing a single frequency can cause co-channel interference affecting uplink throughput
- An internet connection coverage can be extended via a multi-hop network using an IEEE 802.11af devices
  - Maximum throughput is 3.25 Mbps (downlink) and 3.16 Mbps (uplink) at a maximum power of 20 dBm with MCS 3
- To avoid co-channel and adjacent channel interference, two distinct frequencies are employed for each hop: 659 MHz and 593 MHz for hop 1 and hop 2, respectively

Summary

Research Publications

- R. Nordin, H. Mohamad, M. Behjati, A. Kelechi, N. Ramli, K. Ishizu, F. Kojima, M. Ismail & M. Idris, “The World-First Deployment of Narrowband IoT for Rural Hydrological Monitoring in UNESCO Biosphere Environment,” International Conference on Smart Instrumentation, Measurement and Application 2017 (ICSIMA), Nov 2017
- A.S. Bañacia & A. Montejo, “Implementation of a Multihop Network at the University Campus Using an IEEE 802.11af Compliant Network,” International Symposium on Wireless Personal Multimedia Communications (WPMC), Dec 2017

Highlight: Progress & Achievement *(Dec 2016 – Nov 2017)*

- Face-to-face meeting in March 2017 (Kuala Lumpur)
- Malaysia:
  - NICT WiSUN equipment transfer to Chini Lake
  - WiSUN and LoRa installation and experiment at Chini Lake
- Philippines:
  - NICT TVWS equipment transfer to USC
  - Experimental work for NICT IEEE 802.11af devices for fixed location, multihop deployment and multi-floored at USC
  - TVWS deployment for disaster response at Surigao
- Two research papers published

- Upcoming activities *(Dec '17 – Mar '18)*:
  - Face-to-face meeting, further experiments and project report

Thank You!