MUHAMMAD SYAFIQ BIN SAMSUDDIN B.ENG (HONS) ELECTRICAL & ELECTRONIC SEPTEMBER 2013

DEVELOPEMENT OF WIRELESS SENSOR NETWORK FOR LANDSLIDE EARLY WARNING SYSTEM

MUHAMMAD SYAFIQ BIN SAMSUDDIN

ELECTRICAL AND ELECTRONIC ENGINEERING
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By

Muhammad Syafiq Bin Samsuddin

FINAL PROJECT REPORT

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Universiti Teknologi PETRONAS
Bandar Seri Iskandar
31750 Tronoh
Perak Darul Ridzuan

CERTIFICATION OF APPROVAL

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A project dissertation submitted to the
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Approved: ___________________________

Dr. Micheal Drieberg

Project Supervisor,

UNIVERSITI TEKNOLOGI PETRONAS
TRONOH, PERAK
JANUARY 2014

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

____

Muhammad Syafiq Bin Samsuddin

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Abstract

Landslide is a massive catastrophe occurring all around the world and causing thousand of fatalities throughout the year. It is also ranked as second disaster in the level of destructiveness. The awareness on landslide issue has rise since 1960s, somehow there are still lack of technology developed to mitigate the risk of landslide occurrence. The existed technologies produced are highly sophisticated plus expensive. The campaign introduce by the local authority also did not enough to enhance awareness to prepare, and to reduce the impact of landslide. To solve this, this project will develop a wireless network system (WSN) for landslide early warning system which will alert the possibilities of landslide occurrence for further action and mitigation. Several sensors will be chosen to measure monitor the significant factors which possibly induce landslide. The effectiveness and robustness of the system will also be evaluated throughout the project via slope model and data acquisition in Moteview software.

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1. Introduction

1.1 Background Study

Landslide is one of the unpredictable catastrophes which could cause fatality and loss of assets. It is also ranked after earthquake and droughts on the scale of destructiveness [1]. This is a worldwide problem where landslide has put the community who lived nearby hills or housing area on highland at stakes where it could be happening any time without warning. Landslide is named after an activity of soil or rock movement from high land to low land structure due to lose of soil strength and instability involving several factors. Since 1973 to 2007, total of 440 landslide cases has been reported in Malaysia [2]. Based on the incidents, approximately 600 people reported death and cause million of loses. The most popular tragedy in Malaysia was a landslide nearby Highland Tower condominium which resulted 2 block of building collapse down on ground, this catastrophe has cause 48 death and RM 184.9million loses [2]. This tragedy has reflects to the community on how serious it is and makes the needs of technology to mitigate the risk on demand.

Nowadays, Malaysia is still lacking with landslide detection technology where most of the hill side area is manage by frequent checking and observation or it is called as slope management. Authorities also provide guideline and campaign promoting the activities of managing the by slope by observing water flow activities rock movement and many more. Somehow, the practice did not offer constant monitoring system to monitor soil or water flow activities around on the slope area. Nevertheless, the existed technologies are too expensive and require sophisticated equipment such as satellite to do the monitoring on risky landslide area. For that, this project will helps to figure the most significant factor or interrelated factors which can lead to landslide. Besides, a wireless network remote sensor will be developed to provide reading to the base station and alert warning to the area for evacuation if necessary.

1.2 Problem Statement

Landslide occurrence is a result of the impact of several factor which happening around slope area. Today, there is still no clear description on the correlation of landslide physical factor which can be used to trigger alarm for landslide alert on dangerous level based. By having dangerous level based, several alarms can describe and alert the society on how serious the situation is.

The lacking of slope soil activities monitoring system is huge concern in worldwide. Many countries have experienced losses of life and asset due to landslide. It is unpredictable, but with monitoring system, we can analyse the chain of factor that might lead to the slope failure. The existing technology from west has applied highly sophisticated system by using satellite mapping to monitor soil moving activities and estimate volume of rain fall on the hill side which may cause slope failure. Somehow, this mapping technology requires high amount of expenses.

Besides that, current mitigation implemented by government agency which is Jabatan Kerja Raya (JKR) is to promote frequent observation on slope activities, water flow and soil movement to the respective developed area near by the hills. This method is basically unreliable because it is commitment based method. Furthermore there are areas which hardly accessible due to land structure and obstruction. Due to this, we need a maintenance free technology which can be placed on the design area and able to monitor the slope of the hills all day long.

1.3 Objectives

The main objective of this project is to come out with a wireless sensor network (WSN) technology which can provide early warning system to landslide activities. In order to achieve this main objective, several objectives also have to be achieved. The sub-objectives are described as follows.

- To determine the physical factors which lead to landslide activities. With existed literature, the factor will be determined to see the correlation which can caused landslide. Data and graph will be retrieved to investigate the level of the landslide risk and occurrence.
- To develop a wireless sensor network which can response dynamically to landslide early signs of impending landslide. Multiple sensors will be attached to the system and would be able to come out with reading to the respective physical factor of soil. Based on the reading, early warning sign should be able to be reported to base station for monitoring and early warning if necessary.
- To evaluate the effectiveness of the system in responsiveness, maintenance free monitoring equipment, long lasting, robust to withstand the weather and any disruption. This prototype will send continues signal to base station for real-time monitoring application. It is also must be affordable, easily installed and applied to design area. As the current technology are expensive and require sophisticated technology, this project will use Moteview software to monitor and provide data acquisition reading on the internal slope activities.

1.4 Scope of study

The scope of study is to figure out the physical factor of landslide occurrence basically in Malaysia. A prototype also will be developed to be tested on a slope model by using Moteview Software for data acquisition and alert.

2. Literature review

This chapter will describe and summarize the overview of landslide, theory involve, factors of landslide and current mitigation technology which basically explained the important part of the project.

2.1 Overview of landslide

Landslide is worldwide problems which occur every year and caused lost of life and asset. It is also called slope failure. Landslide is basically a process of movement of soil from higher to lower level of ground and caused by several factors. In general the factor of slope failure can be by natural forces, human activities, rainfall, earthquake, construction and many more [3]. In November 2008, the first world landslide forum was organized at United Nation University, Tokyo, Japan. From the studies, statistic shown that, most of developing countries really affected by landslide [4]. Based on statistic published by The Centre of Epidemiology of Disaster (CRED), 17% of world's fatalities due to disaster contribute by landslide catastrophe [5]. Lack of technology, awareness and knowledge on the disaster has cause the impact of landslide greatly experience by community. With disaster risk knowledge and management, people will know how to act and alert their people in time and prepare for natural hazard [6]. In Malaysia, the geological the area of land consist of hilly range is measured to be approximately 35% and 5% consist of mountain which classified as land with high above 1300m from sea level [7]. Since 1973 to 2007, 400 landslide cases has been reported and causes more than 600 fatalities [2, 7]. Graph in Figure 1 below is the number of landslide event per-year

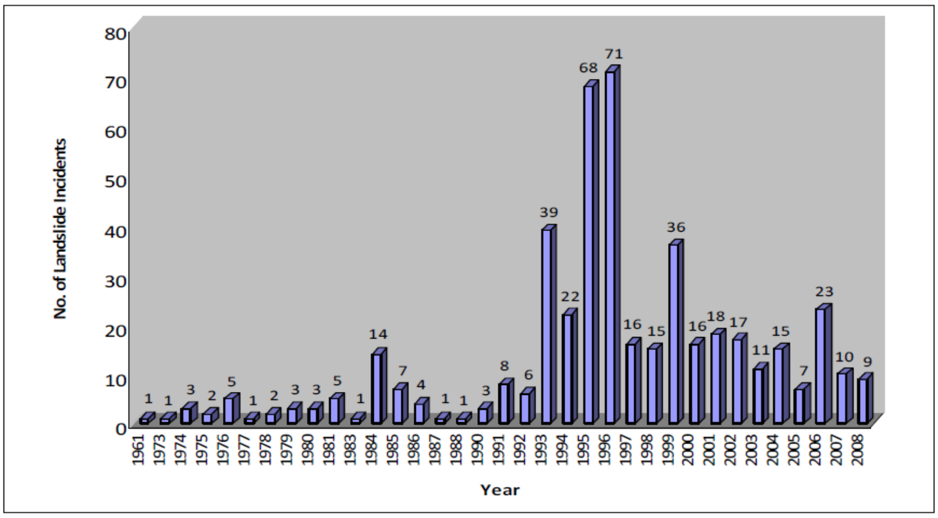


Figure 1: Number of landslide incident in yearly based [7]

Figure 2:Heavy rain cause the landslide in form of mud flow following the alluvial fan at Camuri Grande, Vargas, Venezuela [8]

One of the worst landslide in the world occurred at Venezuela in December 1999 where approximately 30000 reported death and million losses of properties. The landslide debris flows in form of mud caused by rainfall in accumulation of 293mm in the first week of December 1999 [8]. Heavy rain cause instability as it causes change in water table height, increment in pore water pressure and decrement of shear strength as the moistures level is height [9]. Increment value of those factors stated becoming the factor of the landslide. Figure 2 is the tragedy picture taken during mud flow from the mountain following the alluvial fan to the settlement area.

Figure 3: The debris flow hit the pile foundation of Highland Tower landslide caused 2 blocks of tower to collapse [2].

From 49 cases which studied in Malaysia by Gue and Tan entitle Landslide: Abuse of The Prescriptive Method, 2006, 60% of the cases are found as failed man-made slopes due to inadequacy of design and low knowledge of the soil properties and characteristics [10]. The rest are caused by natural activities where contributed by natural factor such as rain and many more. As mentioned in background, the collapsed of highland tower 1 and 2 condominiums (Figure 3) nearby hill side are also caused by land slide. This is due to the underground water flow caused by inadequate drainage nearby the hills and heavy rain experienced in several days. The debris recorded to flow about 120m from slope failure site with rupture width of 90m consisting $40{,}000m^3$ of debris soil [11]. The debris exerted force to the foundation pile of the blocks and caused failure of underground pile structure which resulted the building to collapse.

2.2 Landslide theory

Landslide is classified to several types based on the rate of the process and failure characteristic. Fast landslide is the result of generation of forces which cause the acceleration with respect to soil mass [12].For speed, landslide motion is divided to 7 classes referring to its velocity which are, extremely slow $(5 \times 10^{-7}\mathrm{mm/s})$, very slow $(5 \times 10^{-5}\mathrm{mm/s})$, slow $(5 \times 10^{-3}\mathrm{mm/s})$, moderate $(5 \times 10^{-1}\mathrm{mm/s})$, rapid $(5 \times 10^{1}\mathrm{mm/s})$, very rapid $(5 \times 10^{3}\mathrm{mm/s})$, extremely rapid which the velocity is above those stated [13]. Based on the speed classification, it can help the monitoring unit to classify and provide specific alert to community on the landslide movement either is slow of fast speed. For failure characteristics, it can be divided to 5 categories which are, fall, topple, slide, spread and flow [13, 14]. For fall and topple category, it basically involving slide of rock and hard soil which lost stability from a high slope. For slide, spread and flow cases, it involves soil structure in condition based. If the soil structure is in form of mud, it is likely to undergo landslide in flow characteristic.

Landslide is worldwide problems which occur every year and caused lost of life and asset. It is also called slope failure. Landslide is basically a process of movement of soil from higher to lower level of ground and caused by several factors. In general the factor of slope failure can be by natural forces, human activities, rainfall, earthquake, construction and many more [3]. In November 2008, the first world landslide forum was organized at United Nation University, Tokyo, Japan. From the studies, statistic shown that, most of developing countries really affected by landslide [4]. Based on statistic published by The Centre of Epidemiology of Disaster (CRED), 17% of world's fatalities due to disaster contribute by landslide catastrophe [5]. Lack of technology, awareness and knowledge on the disaster has cause the impact of landslide greatly experience by community. With disaster risk knowledge and management, people will know how to act and alert their people in time and prepare for natural hazard [6]. In Malaysia, the geological the area of land consist of hilly range is measured to be approximately 35% and 5% consist of mountain which classified as land with high above 1300m from sea level [7]. Since 1973 to 2007, 400 landslide cases has been reported and causes more than 600 fatalities [2, 7]. Graph in Figure 1 below is the number of landslide event per-year

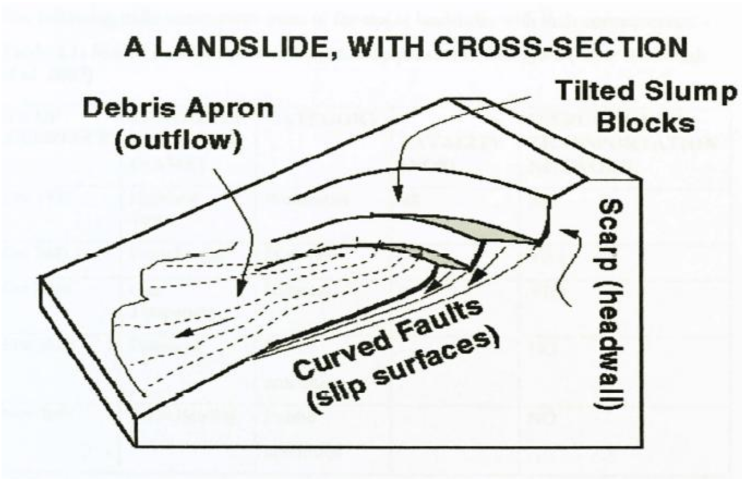


Figure 4: landslide cross section sample [14]

Figure 4 is showing the cross section of landslide in the form of debris flow. Form the figure we can see that the slip surface has its own curve and produce several tilted slump blocks after failure.

The fact above is actually a result from several factors which basically affect the shear strength of the slope structure. As agreed different soil has different characteristic and strength, but the factor which affect the stability of the slope can be the same for example, high poor water pressure which basically caused by rain, infiltration which basically a natural process for a structure a achieve stability. A study done by Suzanne & Farrokh, 2005 on the factor inducing landslide in Italy has come out with several factor which are precipitation and infiltration contribute the highest percentage of 69.4 % to the landslide occurrence. Followed by erosion 13.9%, human effects 7.3%, earthquake 3%, ground water variation 1.7% and other factor 4.7% [5]. In general the most common cases of landslide is because of heavy rain which triggered the change the slope physical characteristic which may induced landslide. It is different from earthquake where the soil structure is shaken and the movement cause the cohesiveness loses in several areas causing rupture in structure.

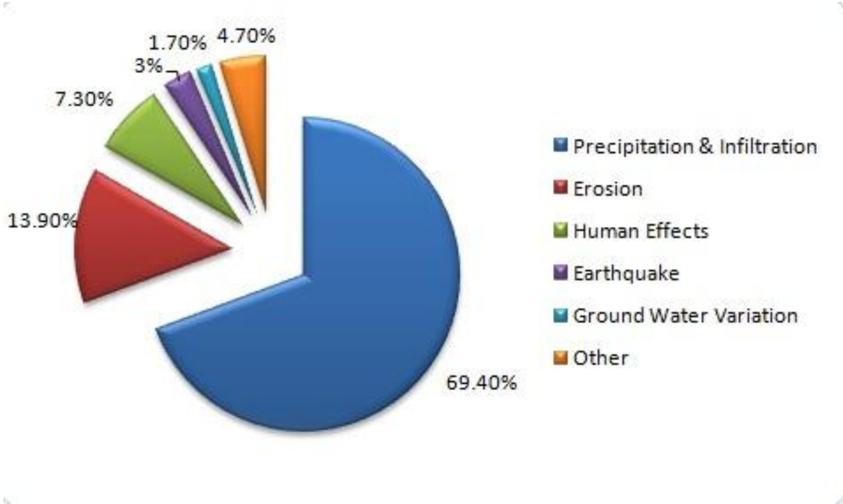


Figure 5: Landslide triggering database in Italy [5]

Referring to the Policy and Institutional Framework for Landslide Mitigation and Risk Reduction has come out with a map of contributing factor to land slide occurrence. It was divided to several classes of factor which are human made factor, geological factor, hydrological cause, morphological cause and physical cause [15]. The detail of the factor is shown in the Figure 6 below.

Figure 6: Landslide contributing factors[15]

2.3 Landslide triggering factors

As stated earlier on the landslide factor studied at Italy, the causes of landslide mainly on the infiltration or rain, followed by others factors which are earthquake, ground water variation and etcetera. In study done by [15], they have come out with several triggering factor to landslide occurrence which summarize in figure below. Based on the triggering factors, earthquake is rarely become the landslide initiate in Malaysia but still there are several cases occur which basically at Sabah and Sarawak region. For volcanic eruption, Malaysia has never experience such factor as Malaysia located far from the Pacific ring of fire that mainly caused a region to experienced volcanic eruption.

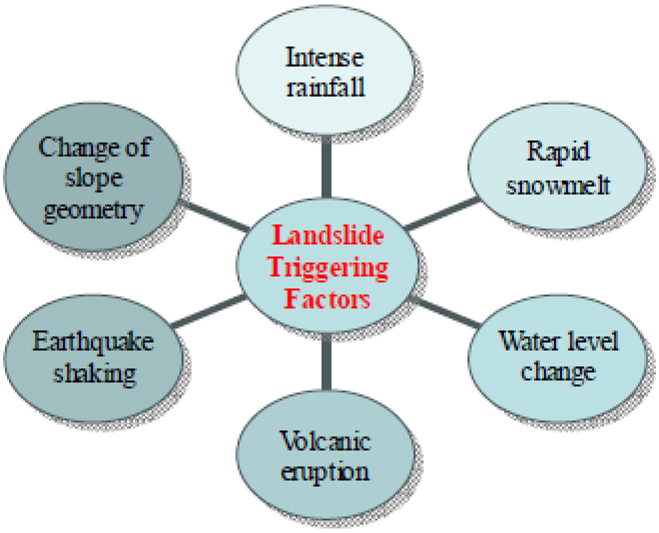


Figure 7: Landslide triggering factors [15]

For landslide occurrence, the factor induced landslide can be divided to two categories which are internal and external factor. Some of the external factor are the slope angle, slope surface and anything can be configured above ground and for internal factor its consists of ground water, subsurface structure and movement of water [16]. Based on study done by F. Nadim et al on probabilistic stability analysis for individual slope in soil rock come out with several sensitive factor to measure probability of landslide which are the shear strength, pore pressure, uncertainty strength due to water under soil and many more [17]. Based on the study, there is several common characteristics study by the researchers which are the pore water pressure and underground water or moisture level. The increment of pore pressure and moisture in soil properties will lead to the depletion of shear strength which will induce landslide.

2.3.1 Internal factor

Pore water pressure can be defined as the pressure exerted in ground water in between soil and rocks which there are existence of gaps or pores. The increment of pore water pressure may create stress and cause instability to soil structure [18]. Low permeability of soil becoming the aid for pore water pressure to increase by causing the pores to be water bank [19]. Pore water pressure also caused buoyancy effect to the shear strength of the soil structure. That is why negative pore water pressure in soil structure on slope is very important to keep the slope stability [20]. In a study done by C.V.Robert on The Near and The Far of Pore Pressure During Landslide and Earthquake Rupture came out with the minimum pressure exerted which make the landslide possible to be induced is 48kPa [21]. From this statement we can conclude that to induce landslide, below 40kPa should be the save region and above 40kPa alert should be given for further investigation and preparation for incoming possible landslide. Pore pressure sensing only, would not be the accurate way to foretell the slope instability will occur [5]. Which mean the other factors are also has to be taken into account to have a reliable indication to foretell the slope failure indication. To measure pore water pressure, pore-water pressure gauge or pore pressure transducer can be used.

Soil moisture content really dependent of the level of water infiltrate on the soil. It is also correlated to the pore water pressure which the changes cause by water [9]. But for soil moisture content it is basically scaled on the level of water absorb by soil element. The highest the soil water content will change the soil characteristic to mud form. Based on study on Instrumented Model Slope Failure due to Water Seepage states that, critical region of slope failure to start to happen is when the soil moisture in volumetric water content (VWC) reaches θ=0.42 [22]. These results find its complement with other experiment done by other researcher.

Soil movement also can be considered as internal factor of landslide as it may occur naturally. With clays soil type, the shear strength is low where from experience, landslide may occur without any provocation from the other factor [12], beside the possibility from landslide to occur getting higher with contribution of other factor.

2.3.2 External factor

For external factor stated earlier (refer to landslide theory and figure 6), the common factor of landslide which basically one of the causes for slope failure all over the world is infiltration. The higher the amount of rain receives on several areas, the higher the tendency of slope failure to occur. For the record, most of mountain slope failure across the world caused by infiltration [23]. By studying the average rain receive in several area, we can estimate the risk level if the area start the experienced heavy or prolong rain which the rain water level spike more than the average. To measure rain intensity is the best way to predict the possibility of landslide in the slope area as it is easily measured using rain gauges and the reading can be used to compare with the average rain received on the area. the other external causes are quite subjective to be measure such as volcanic eruption and earthquake. It is because the impact of these two factors depends on the centre of occurrence which distributes different forces as it goes to a distance.

Even in several areas, earthquake is a rare issue to be heard but the earthquake like phenomenon is likely to occur by construction work in the area. This is due to the operation planting the pile underground which required piling activities which may cause vibration waves to be distributed around the area. In many cases of landslide due to earthquake, the soil structure tend to segregate from in natural form as the impact of vibration [24]. The cracks pose high risk of landslide as the strength and the stability of slope changes. Referring to the output of world earthquake conference, in acceleration of $1.5m/s^2$, slope stability will start to reduce and may induce landslide for prolonged vibration [25].

Shown in Table 1 is the summary of internal and external factor which use to help with decision of choosing the significant factor and appropriate sensor to be used in the project.

Table 1: Summary of landslide triggering factor, effect and sensing advantages/disadvantages

Type of Factor	Physical Factor	Effects on Soil Stability	Sensing advantage/disadvantage
Internal Factor	Pore Water Pressure	• Reduce shear strength • Induce buoyancy force • Reduce frictional force of soil structure	• Indicate the state of pressure exerted on soil structure
	Moisture of soil	• Indicate the soil properties form (mud, dry, semi-wet) • Reduce adhesiveness of soil structure	• Indicate the soil form and characteristic
	Internal movement	• Changes in slope stability • Produce cracks/ segregation in structure	• Indicate the slight movement of soil structure
External factor	Infiltration / rain	• Contribute to the increment of pore pressure and moisture value • Erosion	• Estimate the rain drop volume. • Inefficient way of sensing because depend on soil structure permeability which can be sense by pore pressure sensor and moisture sensor
	Vibration/ earthquake	• Produce Crack in slope structure • Displacement/movement of soil	• Indicate internal activities such as shaking to indicate possibility of losing slope stability

2.4 Current technology

Based on the study done by Suzanne & Farrokh on landslide risk assessment and mitigation and technology, they have come out with several landslide detection technology classifications and describe the advantage and disadvantage of the technology. The most popular landslide risk detection mechanism nowadays is the application of Geographic information system (GIS). Basically GIS is using several techniques in order to indicate the risk of land slide to occur. One of the techniques is the Resistive imaging (RI), which can be used to map the bedrock thickness layer, water content and view the internal structure of slope [16]. GIS is also used to monitor the movement of soil structure via the satellite mapping. This technology can trigger the alarm as the event of land slide start to occur. Besides, with satellite monitoring the amount of rain fall can be estimated. Somehow, satellite mapping experiencing difficulties for area covered with cloud during imaging, especially during heavy rain where cloud surrounding the area and real-time prediction cannot be done accurately due to this disturbance.

There are several other technologies classified in landslide detection which are LiDAR (Light sensing Distance Radar) which sense in distance by analysing the reflected light, InSAR (Interferometric Synthetic Aperture Radar) which map the reflective wave to analyse the movement or displacement of structure, weather radar and many more. [5], state that these technologies facing issue with the image resolution quality which will affect the measurement and analytical component.

2.5 Landslide Mitigation in Malaysia

Basically in Malaysia, the landslide risk mitigation is done at most of man-work slopes which located at the expressway. Based on statistic shown that there are 149 hills area nearby the expressway propagate high tendency of landslide. Early warning and real time monitoring is done to warn the slopes hazards and also alert the authorities to start the preventive measure in order to reduce damage resulted by landslide [2]. There are several mitigation activity done on the respective are area which are setting up a national and regional early warning and real-time monitoring infrastructure, prioritisation of area to be monitored, integrating rain gauges station to several authorities, enhancing rainfall forecasting capacity and installation of instrument at high-risk landslide site area.

Policy making also takes place in the mitigation strategy to avoid possibility of landslide occurrence especially on man-work slope [15, 26]. Every development especially in Malaysia has to follow standard provided by authorities who control by JKR in order to ensure safety in development.

2.6 Wireless remote sensing

Nowadays, wireless remote sensing is widely used in monitoring for real-time update. It offers real-time data collection and analysis to give desired output of response due to several events [9]. The advantage of this technology is they can be integrated with others computer technology such as GPS, Satellite, and even communication mobile own by community. Wireless remote sensing also well known as a good power consumer as it require less power to be consumed plus, ease the maintenance activities rather than changing the dry cell or power source medium frequently. There are many types of WSN mote which are MicaZ, SHIMMER, IRIS, Sun SPOT and many more. Every node offer different capabilities and functionalities [27]. For example, in Random Access Memory (RAM), MicaZ offer less capacity with 4Kbytes rather than IRIS offer 8Kbytes data capacity.

For sensor support, all mote network devices offer the integration of sensor for specific purposes such as light sensing, temperature and many more. Somehow, MicaZ mote did not offer the board sensor. However, the external board of the external source such as Crossbow's board can be used to connect the sensor to the MicaZ mote. For IRIS mote network, the same specification to connect the wireless sensor using Crossbow's board also can be connected with 51 pins expansion connector. Every mote network are basically specialize to be used in several area or purposes for example the SHIMMER device basically used in medical [27]. In the connection, basically wireless-mote is applying X-mesh protocol and flooding routing technique to ensure all data gain is transmitted to the base station (Figure 8).

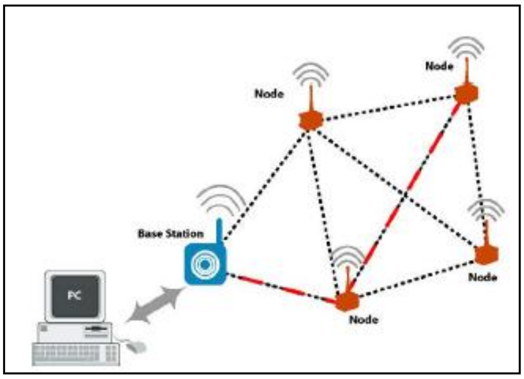


Figure 8: X-mesh configuration

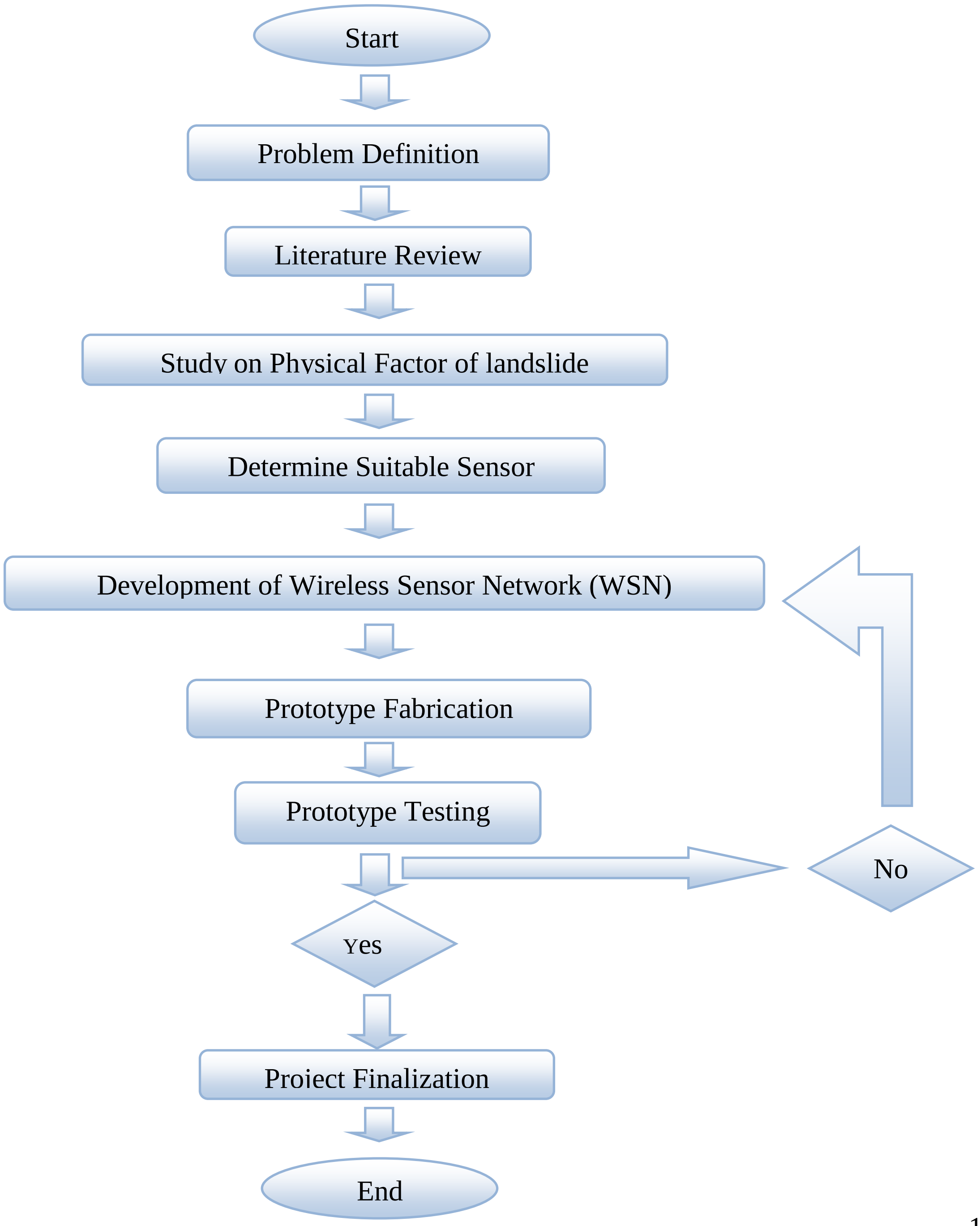
In landslide phenomenon, many factors can be categorized and there are lots of sensor can be used to monitor the physical factor which may induce landslide. As for landslide, the commercially available sensor to detect and monitor the physical factor of landslide is made available. Somehow, less application has found using these wireless sensors to be integrated with landslide detection system. For example, the pore water pressure sensor, moisture sensor and strain gauge sensor can be integrated with mote network [9]. The lack of this kind of sensor integration for landslide detection has offer great prospect to this project to be pursued.

2.7 Conclusion

As for conclusion, literature review section has covered the important info by study and research based regarding landslide. It's including the background, theory, factors and current mitigation done to mitigate the risk faces. Based on the study also, several factors has been look into deep understanding to measure and monitor as it going to be used as triggering parameter in monitoring and triggering the alarm.

3. Methodology

This project basically consist of eight phase where it start with problem definition. In problem definition, the current problem on landslide incident is identified to determine the significant of the project plus, it will be used to come out with several objectives to be achieved at the end of the project. For landslide issue, the problem is reviewed based on the current tragedy, mitigation, detection and technology being used to minimized the impact of landslide catastrophe. The rest of the methodology is shown and describes as follows.



Literature review come as second methodology as it content is basically covered the information on landslide in detail, from the past research and study, the theory and factor of landslide is figured out. Through citation from research article, journal, book and many more reading sources, the literature review will clarify the current status and past report on landslide incident, the factor causing the slope failure and mitigation introduce to alert the community on the risky part of the hill slope.

Next step in the methodology is to study the physical factor and look for appropriate sensor which can be used to determine or measure the respective value or state of the factors. Based on the literature, several significant factors will be chosen to be monitored in order to alert for the risk of landslide. Different factor will require different sensor to be used in monitoring operation. Most importantly the sensor must be wireless sensor so that all data can be capture based on network developed as the sensor integrated in one system.

The fourth stage of the methodology will be the development of wireless sensor network for transmission of signal from sensor to the base station. WSN (wireless sensor network) Moteview software will be used in order to configure connection and transmission of the system. The project will focus on using IRIS mote sensing network too integrate the sensors for landslide monitoring activities. As the sensor is integrated for specific purposes, the raw data output mainly in voltage will be converted to meaningful data via equation which derived from experiment or based on the equation provide by supplier. The tools which will be used in the project are stated in the tools and software later. Based on the signal receive the system will be set to trigger the alarm for warning status if there are significant rise of sensor reading on the factor monitored. There will be an alert pop-up windows come up as the alert mechanism to justify the current status of underground soil activities.

As the WSN is successfully developed and working, prototype will be fabricate in order to secure electrical sensitive component as they might be placed in extreme condition. The prototype should be water resistant and able to withstand high temperature and change of weather. Proper box will be used to accommodate circuitry board and batteries. As for battery, free maintenance and high capacity battery will be used in order to ensure less maintenance need for the sensor system as it might be placed somewhere hardly to access or high. If less maintenance need, it will ease the operation and save lots of time and cost.

The most important part of this project is to test the reliability, effectiveness, robustness and responsiveness of the system to give early warning alarm before landslide occurrence. To test the prototype, a slope model will be developed to represent the real slope situation. By using soil and several rocks, the slope will be used to demonstrate a slope which receive high amount of rain and the landslide process will be carried out. Throughout the process the sensor operation will be constantly monitored to see the sensitivity and the readings given are the same with expected output. Besides, as the sensor continuously updates the reading, the system should be able to trigger the alarm based on the level set for respective reading. The test will be done by demonstrating heavy rain situation as pipe water will be sprayed on the slope model. If the system fails to response to the desired output, the system will undergo the development of WSN network again to change the set up or update the system based on need. For testing, the procedure will basically refer to the typical early warning system block diagram proposed by Laccase & Nadim, 2009 on Landslide Risk Assessment and Mitigation Strategy. The block diagram is as shown below in Figure 9.

For successful testing, the methodology will continue with the finalization of project. Project finalization is basically a part where the documentation takes place. Interim report will be done to state and discuss the result gained. The procedure and operational manual or guideline for the installation of the system will also include in the interim report.

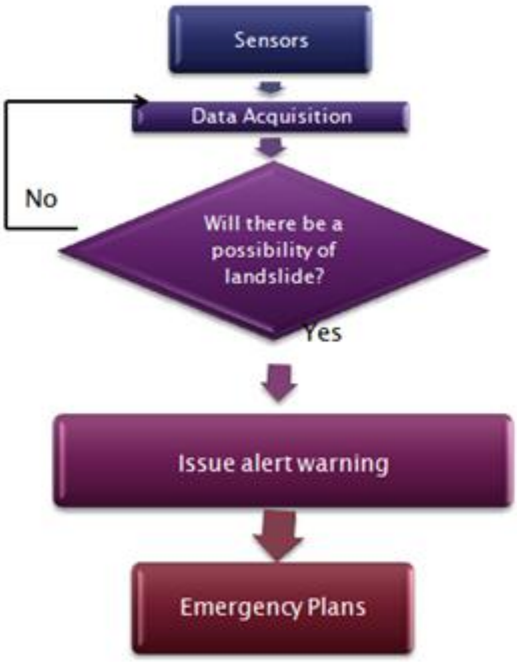


Figure 9: Testing flow procedure based on Landslide risk assessment and mitigation strategy flow chart [5].

3.1 Tools and software

- Computer
- Moteworks Sotware (moteview 2.0)
- IRIS Board (Transmitter and receiver channel)
- MIB520 Board (USB board for data acquisition)
- MDA 300 CA Board (sensor board)

3.2 Gantt chart

Table 2: Gantt Chart

Activities \ Week	1-2	3-4	5-6	7-8	9-10	11-12	13-14	15-16	17-18	19-20	21-22	23-24	25-26	27-28
Problem Statement		■												
Literature Review		■	■	■										
Determine Physical Factor of Landslide			■	■										
Determine Appropriate sensor				■	■	■								
Develop Wireless Sensor Network						■	■	■	■					
Prototype Fabrication/ Slope Model								■	■	■	■			
Prototype Testing											■	■	■	
Project Finalization													■	■

3.3 Key milestone

Throughout the extended proposal, several items have been achieved in order to proceed with the project. One of it is the physical factor of landslide, where there are two categories of factor which are the external and internal factor. Based on the factors, three of the factor has been chosen to be put in focuses which are the external factor that is rain and internal factor which are the pore pressure underground and soil moisture. Those factors will be assigned with respective sensor to enable the monitoring process.

4. Result and Discussion

4.1 Sensors selection

The process of choosing appropriate sensors plays significant impact to the project assessment. This is due to the needs of sensors which fulfil the sensing criteria of the factors which have been chosen earlier. As the sensor node will continuously collecting the data to be transmitted to the base station, the reading taken should be reliable to avoid error warning even there is no landslide possibility. Summarize below (Table 3) is a table showing some comparison of the sensors characteristics based on data sheet available and the requirement need to be fulfilled by all sensors in order to operate in early warning system for landslide detection.

Table 3: Landslide factors and sensors criteria summary

Factors	Detail & Requirement	Sensors	Status
Moisture	Volumetric water content, θ, is use to indicate the states of soil mixture either it is in saturated or unsaturated condition. Min and max VWC = 0 to 1 Alert level = • Dangerous warning at 0.3VWC • Extremely dangerous warning at 0.4 VWC (Saturated condition)	EC-5 Dielectric Soil Moisture Sensor  Specification: • High accuracy up from 0-100% VWC • 2.5-3.6Vdc with proportional output • Compatible with any data acquisition system	2 units available
Internal movement	Internal movement is one of a natural thing to happen in slope area. This is due to the soil degradation and	FSR Force Sensitive Resistors	3 units

	sedimentation of soil. When this happen it create tension which basically can be measured using strain sensor. It is also measured in unit of force which is (N/m^2). Strain gauge will be used to detect internal movement whereby, the detection will be based on the resistance increment on the strain gauge if force is exerted.	 Specification: • Optimum pressure range 700Pa to 700kPa • Output resistance value 10Mohms to 1kohm • Service live more than 1000 cycle.	
Pore water pressure	Pore water pressure has been found the most significant factor for the cause of landslide when raining or broken underground drainage. The water which filled the pore area underground induced force which result on uplift or buoyant force in the underground soil which will cause loose of effective stress between soil particle. Pore water pressure is measured in Newton per-meter squared (N/m^2) or Pascal (Pa). Safe pressure range = <40kPa Alert range= <40 kPa	Standard VW Piezometer 52611020  Specification: • Suitable for most application • Stand up until 350kPa • Plug and play installation.	(cost limitation)

Vibration	Vibration is measured in vibration acceleration which is in meter per-second square (m/s^2). In construction nearby hills area, there is specification stated on the limit of vibration for save development. Limit stated will be the bench point to alert warning for landslide possibility. Risk vibration value = $2m/s^2$	ASSEMTECH-MS24A/30  Specification: • Switching voltage 5Vdc • Output current 24mA

Appropriate sensors have been chosen and still undergo the process of buying from supplier and to be evaluated as the stock ready. Proper termination to the MDA300 sensor board will be done to configure the detection mechanism and output to be displayed in Moteview software.

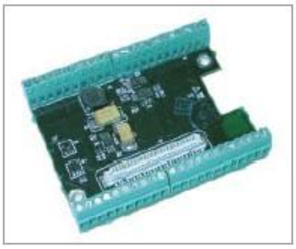
In order to choose the appropriate sensor, deep understanding on the landslide factor and behaviour is needed. Thus, the selection objective is to fulfil the requirement on the factor of landslide. The sensor choosing process should comply with the third objective of this project which is to provide affordable technology for impending landslide monitoring instrument and system, plus it should be easily maintain and installed to the respective area. Three sensors have been successfully gathered due to low cost and comply with the factors requirement. There are the moisture to measure the volumetric water content (VWC) in soil, force resistive sensor (FSR) to detect the deformation or forces underground, and the vibration sensor to detect any form of activities which produce vibration which may caused loose in slope stability.

Somehow, for this project pore-water pressure transducer and vibration sensors are not made available due to the pricing is too expensive and not affordable to be purchased. Due to this cost limitation pore-water pressure transducer application is not included in prototype, but the working principle and purposed is studies for future work and product development.

4.2 Development of Wireless Sensor Network

Referring to the tools use in this project, wireless sensor node provided by Memsic Inc is used to develop wireless network for data acquisitions. Set of Motework tools is use in this project as shown in Table 4 below.

Table 4: MoteWork wireless sensor network (WSN) tools.

Serial Number	Type of Board/ Functionality	Quantity
MIB 520 	USB mote interface board • Act as bridge to connect the IRIS board to base station and communicate with sensor node • Programmed IRIS board based on user needs.	1 unit
IRIS-XM2110CA 	IRIS 2.4GHz mote module • 250kbps, High data rate radio • Enabling wireless sensor network • Acts as transmitter and receiver • Support ad-hoc mesh networking	3 units
MDA300CA 	Data acquisition board • Multi-function data acquisition board with temperature and humidity sensor • MICA2 and IRIS compatible with TinyOS driver support • Equipped with 11 channel 12 bit analogue input	2 units

4.2.1 Software Installation and Programming Manual

MoteConfig is software provided as Graphical User Interface (GUI) from MEMSIC and a platform for programming and node monitoring purposes. This utility offers capability of programming the mote by downloading the program via USB mote interface board MIB520 to the IRIS of other available mote board. Listed below is the step and requirement for Moteview software installation.

- Installation Platform

  To install MoteConfig software, platform used must have these criteria:

  - Windows XP Home OS
  - Windows XP Professional OS
  - Windows 2000 with SP4 OS

  Note that if user are using advance windows, there is no problem because PC do support dual boot operation which user can choose to run advance or previous version windows as long as both windows Operating System is installed in hard drive. To do so, manual for windows dual boot installation is provided in Appendix 2.

- Moteview GUI (Graphical User Interface) Installation

  Before installation, the pc must use NTFS file system and the PC provide administrative privilege for installation.

  - Installation steps:
    1. Insert CD-ROM of any storage device which store Motework Support tools.
    2. Run the Moteview2.0_setup.exe in the Moteview folder
    3. Choose installation directory for example in C:\Program file\Crossbow\MoteView.
    4. Check all square for available installation task.
    5. Follow the installation shield wizard for the process of installing; MoteView application, PostgreSQL 8.0 database service, PostgreSQL ODBC Driver & Microsoft.NET 1.1 Framework

- USB Driver Installation for MIB520 Base Station Gateway
  1. Connect MIB520 board to the PC and let the PC configure new hardware is connected.
  2. When the PC directed to the installation shield wizard, click "Advance" and browse the "USB Driver" in installer storage (CD/flash drive)
  3. Follow the installation process, as the installation done, two virtual COM ports associated with the MIB520 gateway is established. Find out the COM port used for software communication later on by checking in the system.
  4. To check the COM port, click on Windows Start> Control Panel>System> Hardware> Device Manager>Ports (COM & LPT). Take note of the assign port number for future use.

- Mote Programming
  1. Connect Base Station (MIB520) together with IRIS mote to USB module at PC. (MoteView2.0 software will not run unless the MIB520 is connected)
  2. Open MoteConfig windows by clicking the thunder symbol at the top left of the MoteView windows.

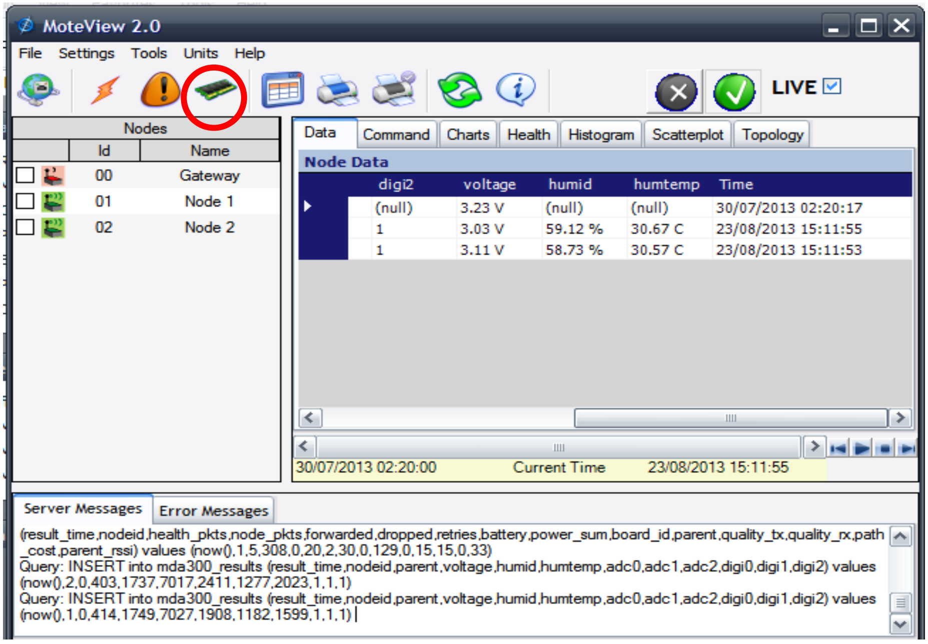


Figure 10: MoteView2.0 windows (In circle: MoteConfig sysmbol)

3. MoteConfig windows will pop-up after clicking the thunder symbol in red circle.

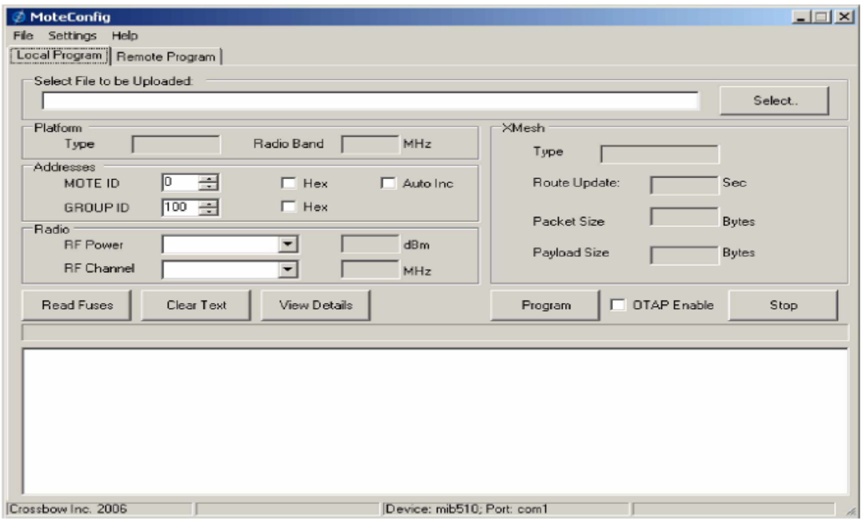


Figure 11: MoteConfig windows

4. Click setting to configure port and USB board used in the system, set the detail as shown in picture. For COM number, different computer is giving different COM number. Choose the highest COM port for programming purposes.

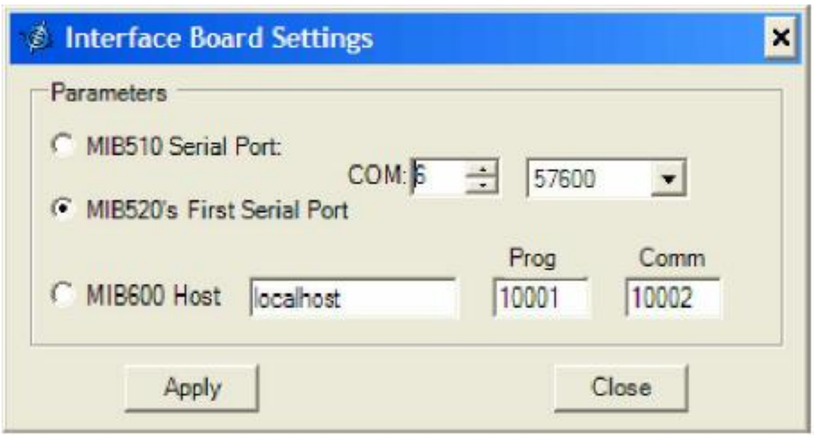


Figure 12: Interface Board Setting Windows

5. After set-up the interface board setting, the IRIS mote is ready to be programmed via USB interface board. Be reminded where all IRIS board need to be programmed before use.
6. Return to MoteConfig Windows under "Local Program" click "Select" to select programming files. Go for "xmesh" and select "IRIS" folder and choose "XMeshBase" folder for base station Program or "MDA300" for sensor node. For programming file choose files with hp (high power). Example: XMDA300_M2110_hp

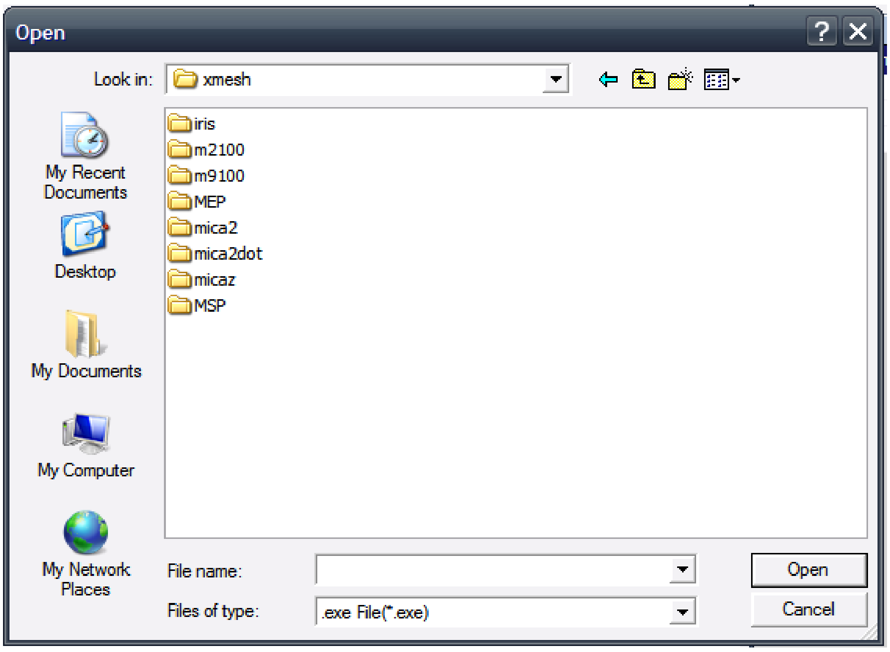


Figure 13: Programming files windows

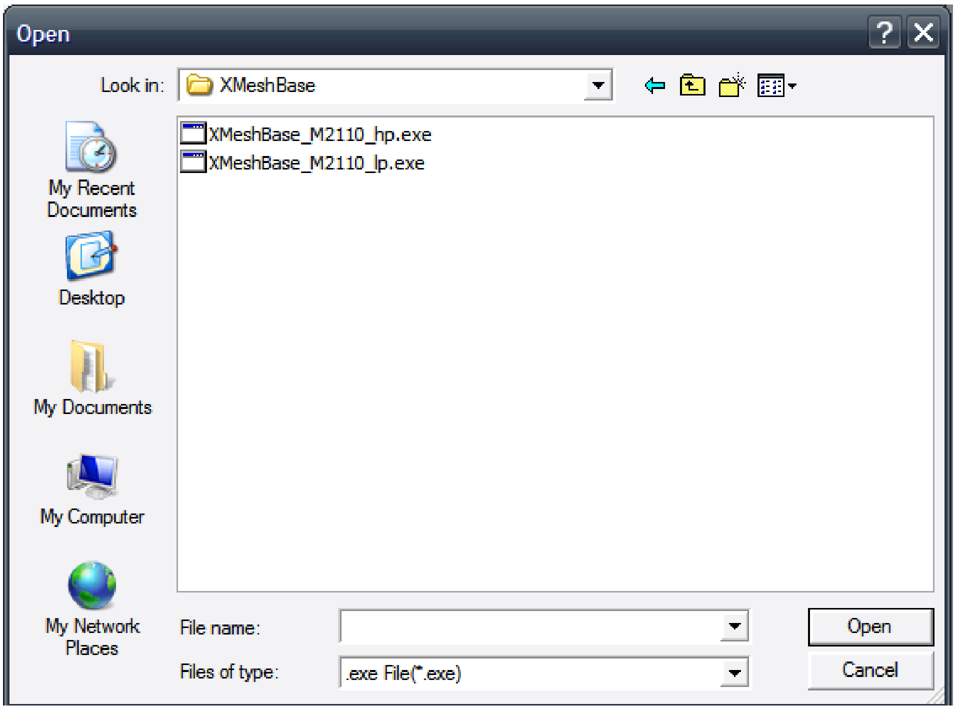


Figure 14: Programming files

7. After selecting the files, click “Program” button to start programming the sesor node or base station. Ensure the base station is programmed with Mote ID “0”.

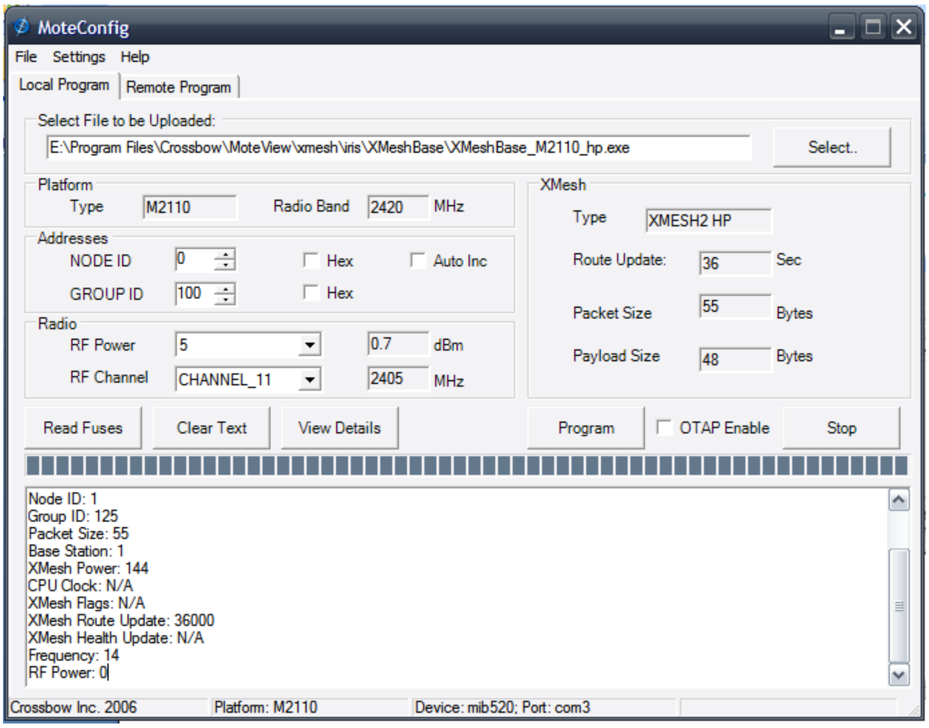


Figure 15: Programming windows in progress

8. To program sensor node, replace the IRIS board which already programmed as base station and connect new IRIS board to the USB MIB520 interface. Make sure the Mote ID is assigned increasing from 1 and above.
9. After programming all nodes, wireless sensor network (WSN) is ready to be set up. Return to MoteView2.0 windows and click the "Earth symbol"

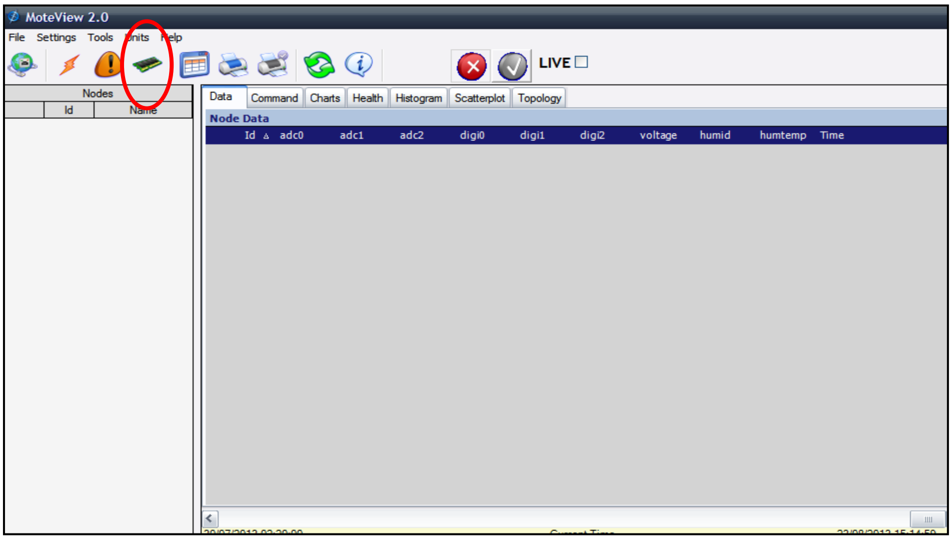


Figure 16: Development of Wireless sensors connection

10. After clicking the "earth symbol", "Connect to WSN" windows will pop up and set the setting as follow and click "Next".

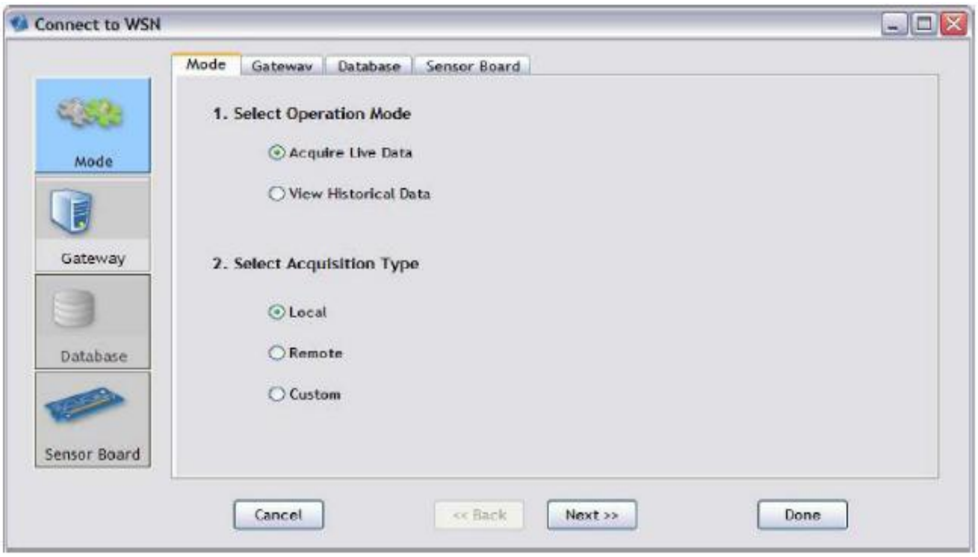


Figure 17: Connect to WSN setting

11. For gateway, choose MIB520 as interface board, and set the serial port to the highest comport available. Can be check as mention at installing USB board interface earlier. Click “Next”.

Figure 18: Gateway configuration

12. As for sensor board, select “XMDA300” as the application name and click “Done”.
13. After clicking done, WSN communication should be automatically established, if sensor node are not exist, add node at node column in MoteView.20 windows and click “refresh symbol”.

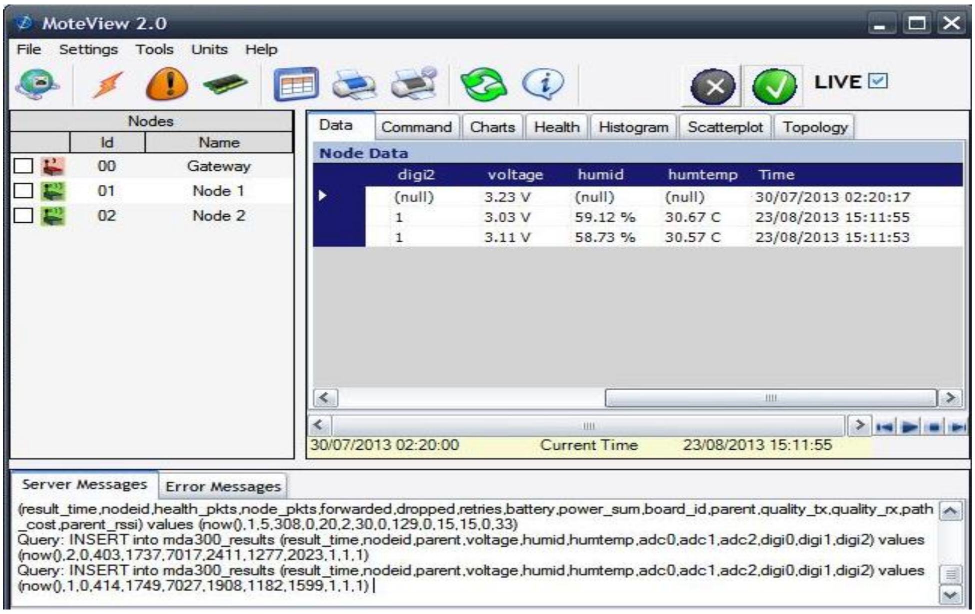


Figure 19: Data acquisition windows

14. All data from sensor boards should be available for real time review. If not, use tools to add node. Additional sensors to sensor board setting are available in MoteView2.0 tools.

Process of WSN development is done by software installation on computer with several requirement need to be followed in order to ensure the installation successful. One base station and two nodes have been successfully configured with special characteristic or identity to ensure the IRIS node may communicate to perform task as base station and sensor node. Furthermore, the unique ID and characteristic include the radio frequency used, signal power, channel and gain to distinguish node from other node from different network. As IRIS is working in Radio frequency bandwidth, it made the configuration to assign frequency easier.

As the configuration process successful, the node IRIS board modules are integrated with MDA 300 sensor board with humidity and temperature sensor built-in in the board. To ensure successful integration of MDA 300 and IRIS module, the Moteview GUI suppose to be showing the reading on moisture and humidity as shown in the Figure 10 in chapter 4. The connection topology also can be reviewed in the software as shown in Figure 20. MDA 300 board offers up to 11 channels for external sensor integration in analog and digital input. With 3 modules which provide excitation voltage from 2.5v, 3.3v, and 5v made MDA 300 suitable to be used for sensor integration in large variant.

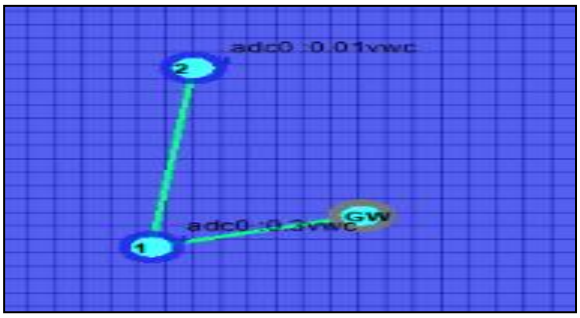


Figure 20: Connection topology

4.3 Data Acquisition

To configure data update, the WSN hardware should first connected to the PC to act as a base station and the other node is switched on with battery ready installed. Green light indicates the board is ready to work and yellow blinking LED indicates the heartbeat of the sensor node. Display below in Figure 21 is the sample of motework tools hardware setup before executing the data acquisition.

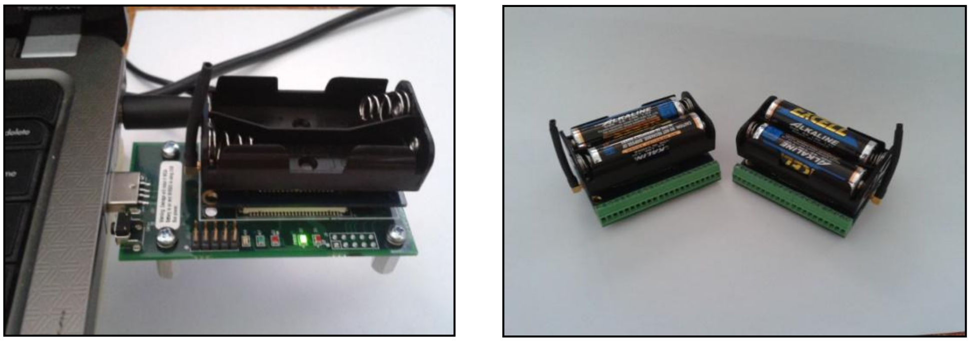


Figure 21: Hardware Setup for base station and sensor nodes.

For data acquisition, the view is available in MoteView windows after the WSN setup complete. Figure 22 below shown, the example of data acquisition based on the available sensor on MDA300 sensor board which there are built-in temperature and humidity sensor.

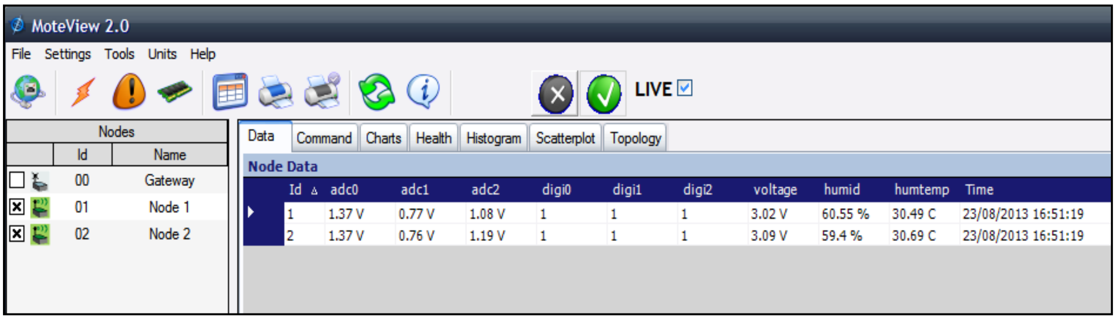


Figure 22: Data acquisition windows

The data in Moteview also available to be viewed in form of chart, histogram and scatter plot. Figures below show the example of the data viewer.

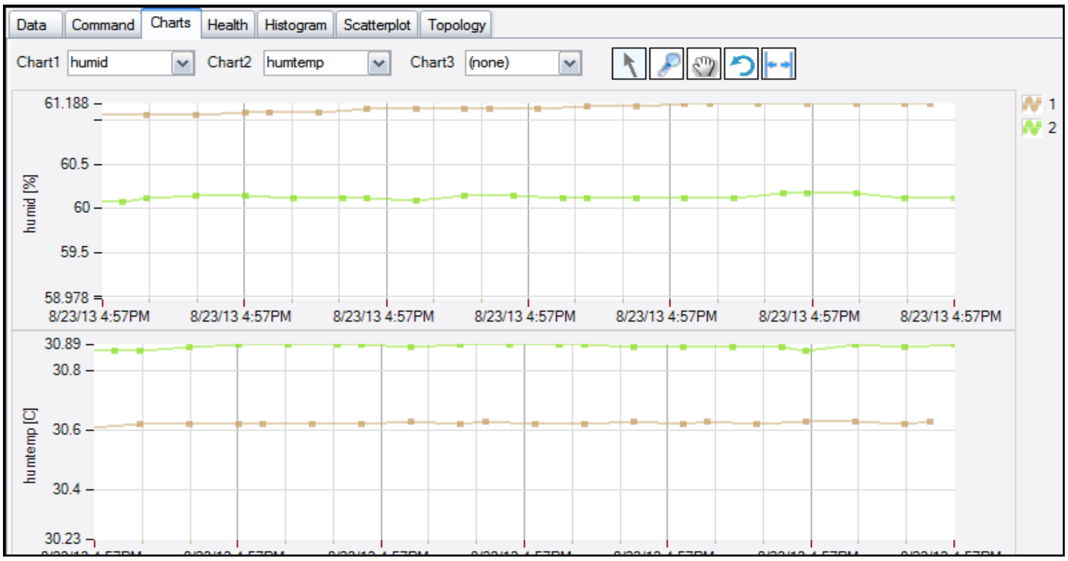


Figure 23: Data acquisition in chart plot for humidity and temperature

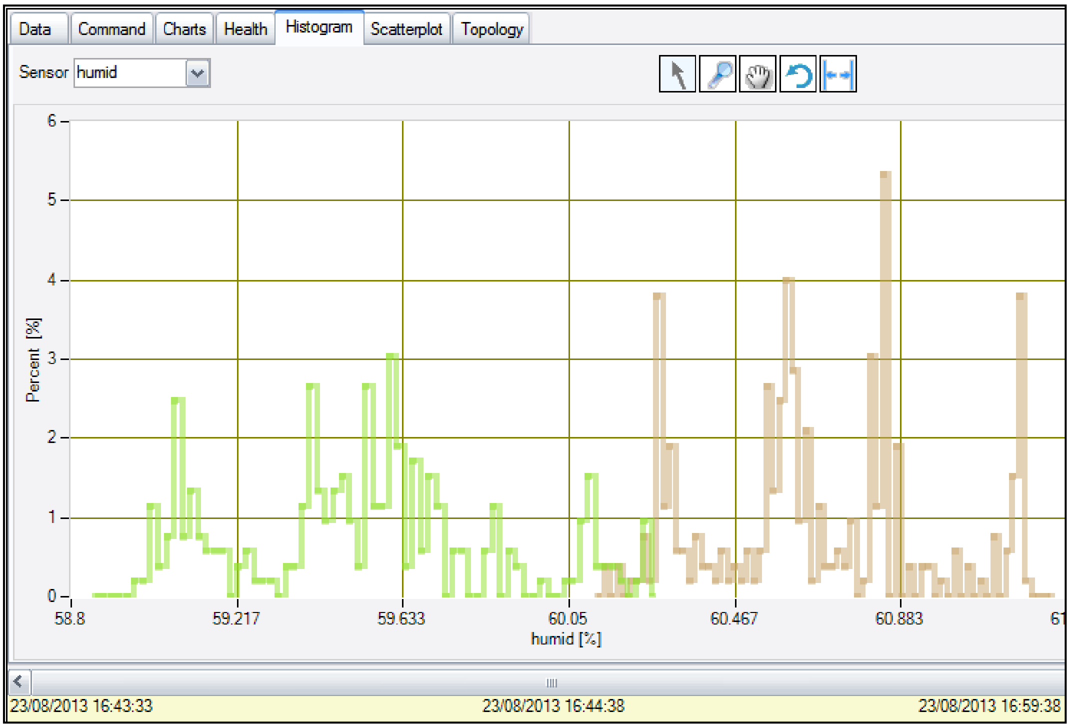


Figure 24: Histogram data for humidity

Based on the data acquisition, the real time value of reading can be configured plus make the real time alert for dangerous reading can be done. The data also can be saved to history data for inspection and also study purposes.

4.4 Sensor integration with MDA 300 sensor board

There are two available sensor available after purchased is made from respective supplier and collect from existed stock. The sensors are moisture sensor and force resistive sensor (FSR). Both sensors have undergone integration processes with MDA 300 sensor board. The connection to the MDA 300 sensor board is as shown in figure 25.

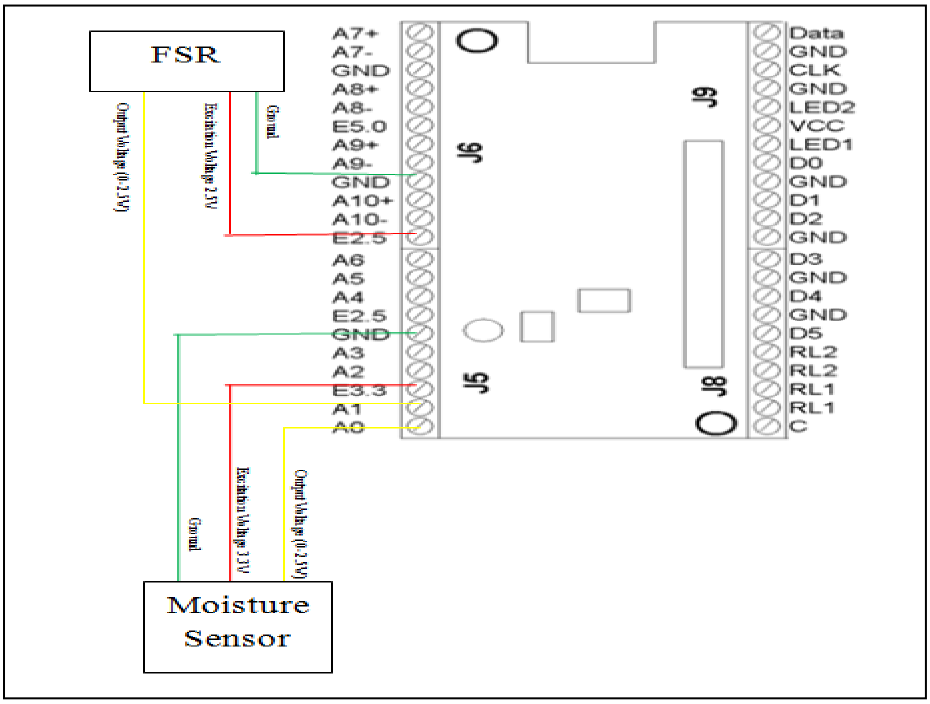


Figure 25: Connection of Sensors to MDA300 channel

4.4.1 Moisture sensor

Decagon probe EC-5 is used in basic application for soil moisture measurement. It is capacitance type of sensor which measures the dielectric between two rods. With minimum of 2.6 to 3.6 volts input requirement, it made Decagon EC-5 moisture sensor well suited with the MDA 300 sensor board for low voltage application. Plus with analog output with one excitation cable (white) and analog voltage output (red), the sensor is easily connected to external sensor connection module at MDA 300 sensor board. As the board is powered up, the sensor will provide raw data in milivolt (mV) which can be retrieved from the Moteview GUI.

An experiment has been conducted to retrieve the straight line equation of the sensor output (mV) versus volumetric water content (VMC). The experiment was prepared with 2 types of soil and the experiment processes are shown in figure 26 and 27 below.

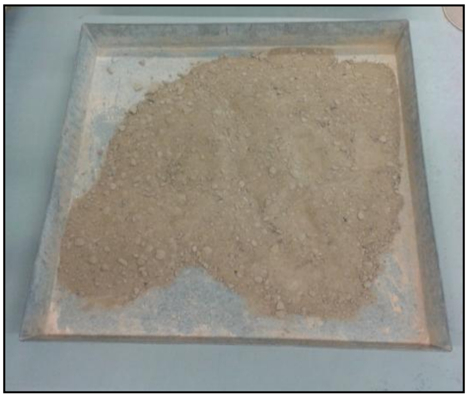


Figure 27: Sandy type soil in dry condition **Figure 26: Clay type soil in dry condition**

The soil was undergone drying process in soil drying oven for 24 hours. It is then collect in container and ready to be mix with water as shown in figure 28.

Figure 28: Soil sample in container

The sample moisturise in the container is then measured by placing the probe in the soil sample as shown in figure 29.

Figure 29: EC-5 moisture sensor immersed in soil sample

The result is then retrieved from the base station connected to PC for Moteview GUI as shown in Figure 30.

Figure 30: Base station for data acquisition connected to PC

The detail of the experimental procedures is attached in (Appendix 1). From the experiment, the result is obtained as follow.

- Clay type soil result:

Table 5: Clay type sample data table

Sample Number	1	2	3	4	5
Mass of Moist Soil (g)	74	74.6	78.7	83.3	97.9
Mass of Dry Soil (g)	74	70.5	70.9	72.2	80
Mass (g) Volume (cm3) of Water	0	4.1	7.8	11.1	17.9
Sample Volume(cm3)	0.314	0.314	0.314	0.314	0.314
VWC	0	0.058	0.11	0.15	0.22
Output Voltage (V)	0.370	0.430	0.480	0.570	0.710

From the tabulated data above, 5 sample of data taken to review the pattern of the VMC increment and output voltage. A scatter plot graph is obtained with straight line fit to come up with the equation as shown below in Figure 31.

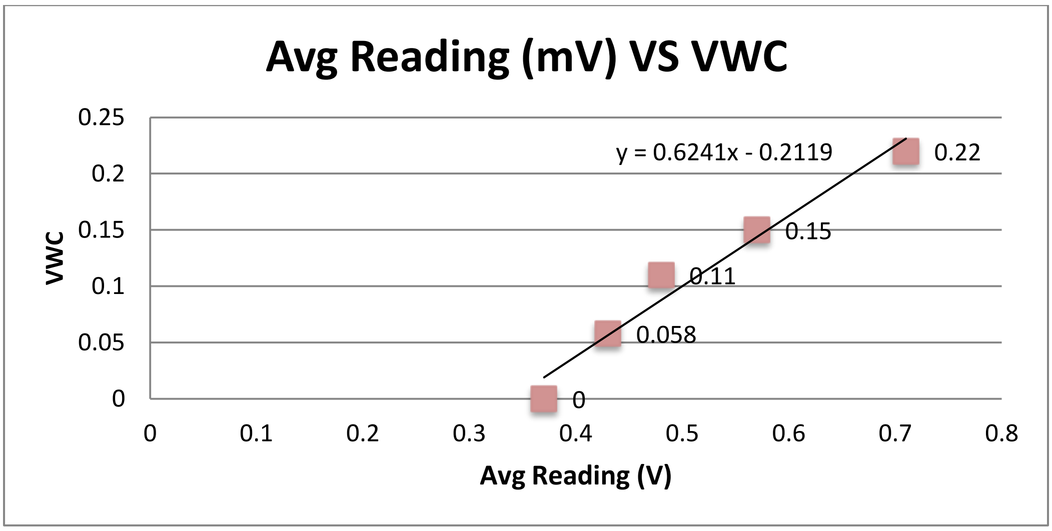


Figure 31: Output voltage versus volumetric water content graph (Clay type)

Graph in Figure 31 is showing the scatter plot data of output voltage versus volumetric water content. From the data taken, the scattering data may be represent in straight line fit which enable the equation on straight line, $y = mx + c$ to be obtained. From the equation m=slope of straight line and c= y-interception value. By using trend line pattern in the Microsoft excel tools best fit of straight line is obtained with equation. As computed the best fit straight line give the output equation of y = 1544.6x + 345.8. As the volumetric water increase the output of the sensor probe will increase linearly.

- Sandy type soil

Table 6: Sandy type sample data table

Sample Number	1	2	3	4	5
Mass of Moist Soil (g)	79.6	86.3	102.3	94.7	86.9
Mass of Dry Soil (g)	79.6	81.1	90.2	79	69.2
Mass (g) Volume (cm3) of Water	0	5.2	12.1	15.7	17.7
Sample Volume	0.314	0.314	0.314	0.314	0.314
VWC	0	0.064	0.134	0.199	0.256
Avg Reading (V)	0.370	0.470	0.620	0.710	0.770

Table 6 is showing the data recorded from the experiment on the sandy type soil. 5 samples of data taken and scatter plot graph is obtained to perform best fit of straight line to gain liner function of the sensor.

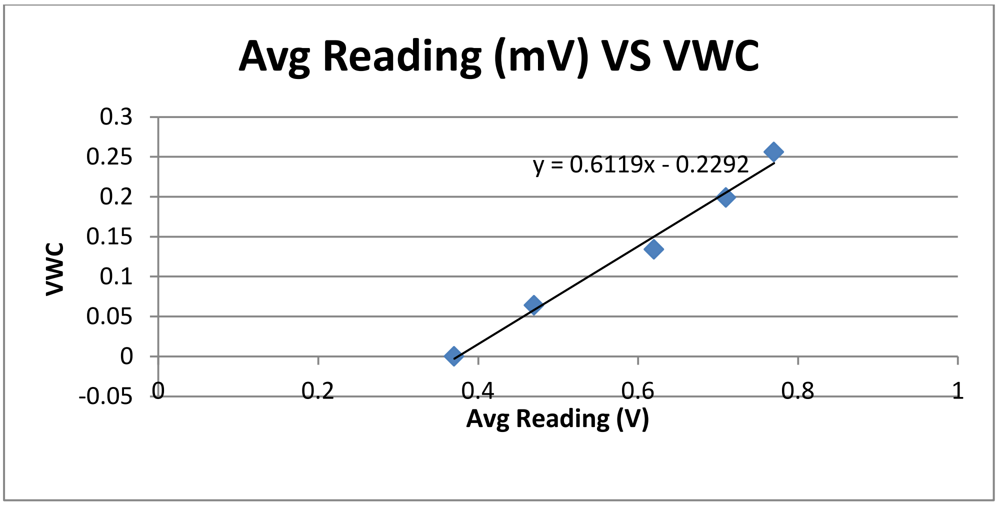


Figure 32: Graph of Output voltage verses volumetric water content (sandy type)

Based on the graph in figure 32, the best fit straight line gives the equation of y = 1613.2x + 377.31 where the slope, m=1613.2 and the y-intercept point c=377.31mv. This equation will be substituted as the constant coefficient (Figure) in straight line for meaningful data reading after raw data in the output milivolt.

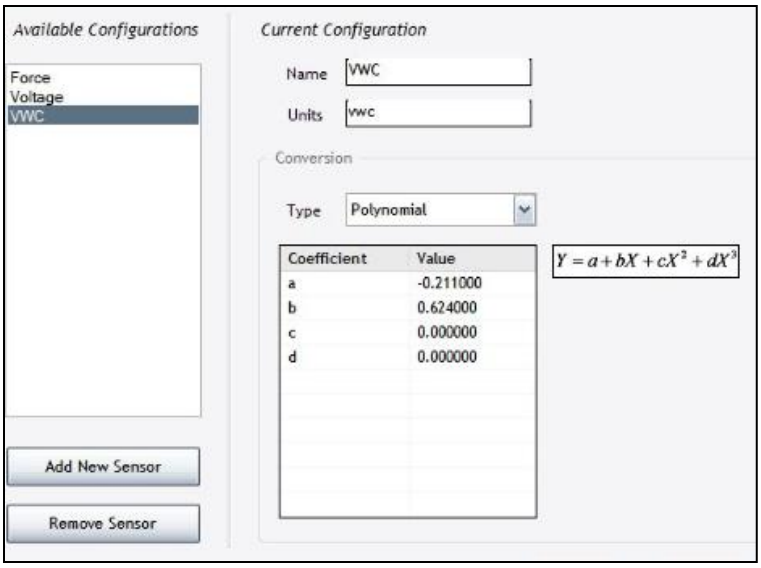


Figure 33: Polynomial coefficient table

4.4.2 Force resistive sensor

Force resistive sensor or FSR is mainly used to determine force exerted in the resistive part which result change in resistance value. Without polarity, the sensor is easily integrated to MDA 300 sensor board for data acquisition. As the force is applied on the sensor the resistance value will decrease per applied force.

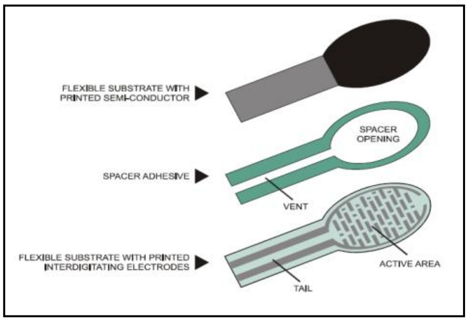


Figure 35: FSR interior material

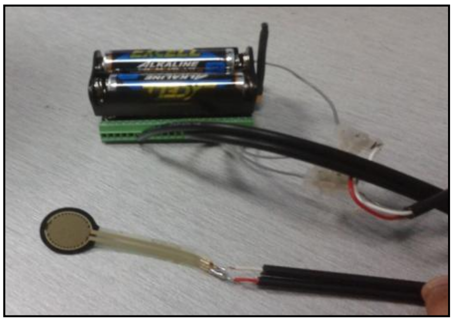


Figure 34: FSR cable termination to MDA300

For force resistive sensor, the resistance value started with more than 1M -Ohm. Per applied forces, the resistance value degrades to low value of resistance. Since, the value of the resistance did not degrade linearly; FSR is not suitable to be used in precision measurement. From Moteview data configuration, the output is given in voltage value thus the increment of decrement of the voltage output depending on the value of resistance changes at FSR. The data output is shown in the circle on the Figure 36 below.

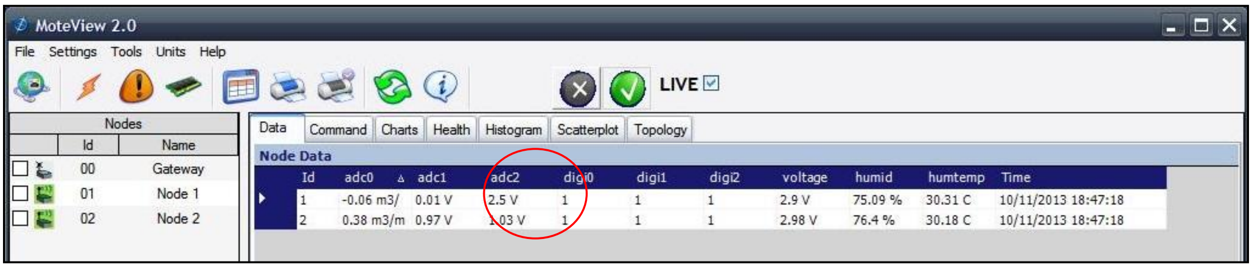
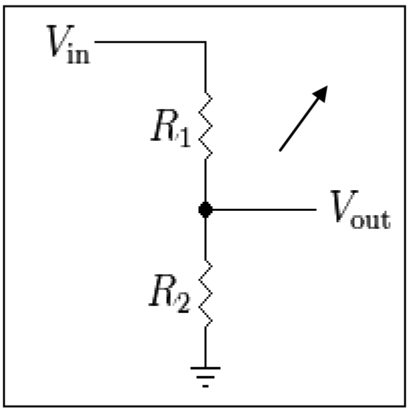


Figure 36: ADC1 output for FSR sensor

Thus, the FSR may play the role of detecting any deformation or movement underground for alert with minimum value of threshold. Shown in Figure 37 and 38 is the schematic for voltage divider and the resistance characteristics where the purpose of having this voltage divider is to get the voltage value vary in every change of resistance. The value of FSR maximum resistance is 100kiloOhm, to produce a very sensitive output; the additional resistance is to be allocated smaller than FSR resistance.



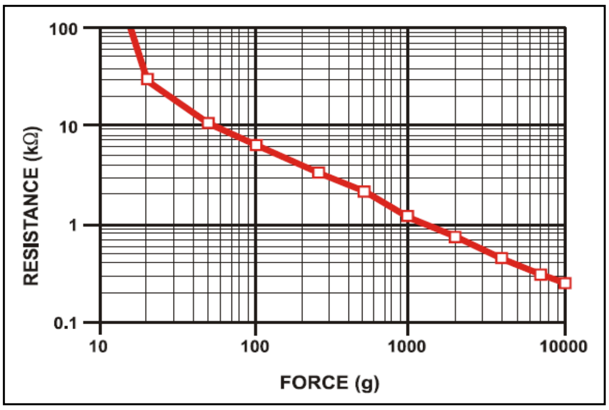


Figure 37: Voltage Divider schematics **Figure 38: Resistance versus Force**

Since the output is measured in Voltage, connection of a voltage divider is made to manipulate the output value to optimize input limit range to MDA 300 sensor board which only accept 0-2.5V input. Furthermore, per-characteristic graph of FSR provided in datasheet the resistance sensitivity is in range of 0.1kΩ -100kΩ. Shown in Figure 33, R1 representing the FSR and R2 is an additional resistance. After calculation, the resistance value which would optimize the output range is 4kΩ. The calculations on minimum and maximum output are shown as follows.

Equation of Voltage divider output:

$$Vout = \frac{R2}{R2 + R1}\ Vin$$

Resistance range optimization:

$$0.1 = \frac{4k}{4k+R1} 2.5 \quad , R1 = 96\text{k}\Omega$$

$$2.4 = \frac{4k}{4k+R1} 2.5 \quad , R1 = 0.166k\Omega$$

With 4kΩ R2 resistance the FSR value will goes in range of 0.1kΩ to 100kΩ. Refer figure34

The values of the resistance per applied forces are not in linear form, which made it is hard to configure the equation for the curve characteristic, thus the Motewiew interface is offering a function of look-up table to substitute the value and the calculation will provide the output based on the average value of two consecutive true value. The Look up table is as shown in Figure 39.

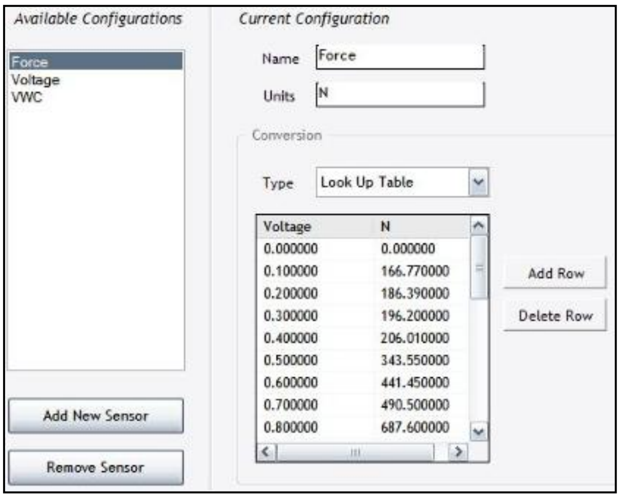


Figure 39: FSR look-up table

4.4.3 Vibration Sensor

Vibration transducer from ASSEMtech (Figure 33) is chosen to monitor the underground vibration on the slope area. Potentiometer is located inside the casing which comply the standard of IP65 protect the circuitry from dust and water. With requirement of maximum 5v voltage, makes this vibration sensor module well suited with low voltage application. This sensor is not included in the prototype as the output configuration given is in digital which need to have coding to read the output.

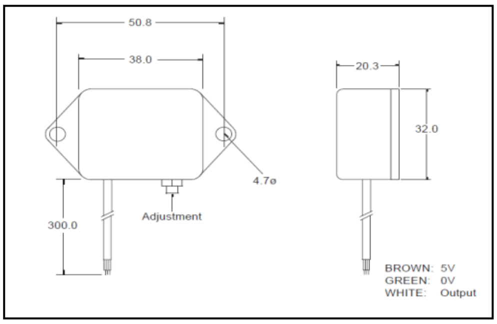
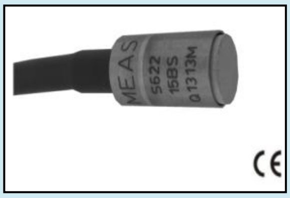


Figure 40: ASSEMtech tilt/vibration sensor

4.4.4 Pore-water Pressure sensor

Pore-water plays significant impact as same as the soil moisture on the slope stability. Both indicate the water table height on the slope area. Somehow, for this project pore-water pressure sensor could not be purchased due to high cost of the product. Several suppliers have been approached and the quotation for a sensors cost more than RM1000 per sensor. Since limitation on budget for FYP purposes, the purchasing process for pore-water pressure is not done and the characteristic of the sensor is studied for recommendation. The characteristic of Pore pressure sensor is shown in Table 7 below.

Table 7: Quoted pore-water pressure sensor

Pore-water Pressure Sensor	Product Detail
EPB-PW Miniature Pressure Transducer Preliminary 	• Titanium construction • IP68 ingress Protection • Pressure detection range 1-70 Bars • Price: £1082 each (RM 5,503.83) • Supplier: StrainSense Lmtd.
Vibrating-Wire Piezometer 	• Stainless steel material • IP68 • Pressure detection range up to 35 bars • Price: RM 2,200 • Supplier: C E Instrument Sdn. Bhd.

Per mentioned earlier, four sensors is meant to be used to monitor and measure respective factor which may induce landslide. First sensor which integrated to the MDA300 sensor board is the moisture sensor. With 2 wires configuration, the white wire is connected to 3.3v excitation voltage module at MDA300, and the red wire is connected to the output module at ADC0. EC-5 Decagon moisture sensor is a capacitive sensor which measures the dielectric at the respective underground area. Raw data output given in milivolt which can be form to a meaningful data result which is in volumetric water content (VWC). To gain VWC, an experiment needs to be performed to demonstrate the relationship between the increments of sensor output with VWC in soil. 2 types of soil is used in the experiment where both are given a near result of straight line slope which for clay type is m=0.6241 and for sandy type m=0.6119. This result portray that the moisture level indicates for different soil types is nearly the same depending on the volume of water dissolve/absorbed by soil. Per stated in literature, an experiment done by department of civil engineering in the University of Tokyo, they found that the critical level of VWC to caused landslide is when θ=0.42-0.43. Per-equation formed via straight line fitting as shown in Figure 28 and 29 the VWC value can be configured based on the raw data (milivolt) to be substitute in the equation.

Force resistive sensor (FSR) is a very basic sensor to indicate force exerted on the area. The resistance value degrades as the force applied to the sensor. Thus, without any force the value of the resistance remains high. This type of sensor is not suitable to be used in the approximate measurement purposes due to the degradation of resistance per applied forces is not linear. As in landslide scenario, slope deformation is a process which indicate risk on soil activities, FSR will only detect any movement or forces applied if there are slope deformation occur and it will indicate high level of alert due to movement which might caused slope instability or even induced a landslide. For cable termination the excitation cable is connected to the 5v excitation voltage module at MDA 300 and the output signal is sent to the ADC1 module located next to the ADC0 module which use for moisture sensor.

For vibration and pore-water pressure sensor, both of these sensors are not yet integrated with the WSN system thus there are no result or out gain for the moment. Due to cost limitation and time consuming on the purchase processes on the supplier site. For pore-water pressure sensor, the process of searching for affordable sensor is still on. If there are no available products to be purchased, pore-water pressure sensor will be included in the future work for further development and modification.

4.5 Slope model development and testing

The third objective of this project is to assess the prototype on the slope model developed. To do so, a case is designed for fabrication purposes to contain the soil sample when the testing of the prototype takes place. Simple design of the soil container is done using Solidwork software to provide proper scale and figure to ease the fabrication process later. Figure 41 below shows the drawing with dimension from Solidwork software.

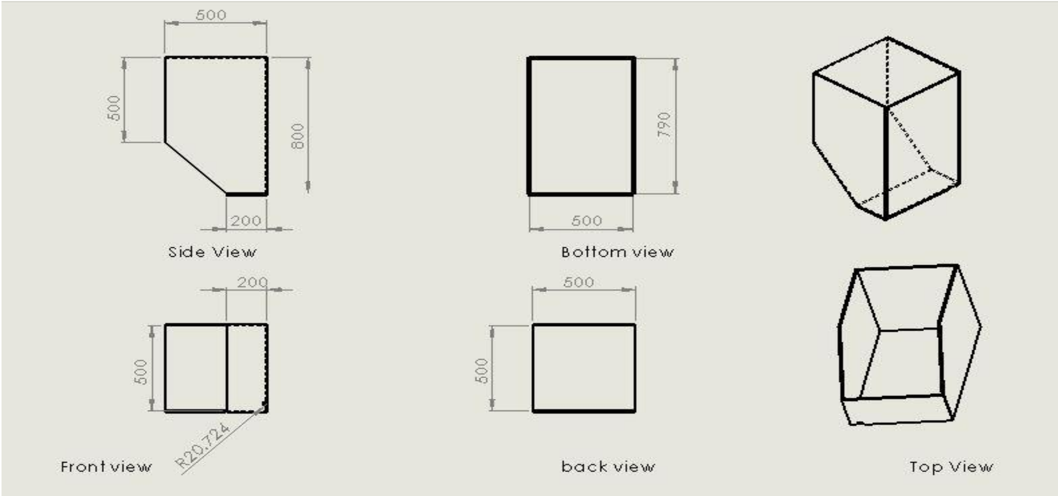


Figure 41: Slope model container drawing model

The slope container should be able to withstand with the weight of the soil sample. Plus, when the soil is pour with water the weight might double of the dry soil. A hole is made in front of the box to enable excess water flow out of the container. Figure 42 below shows the fabricated Perspex container with soil sample placed inside

Figure 42: Perspex container with soil sample

A test has been conducted to verify the responsiveness of the system and sensor plant on the slope model. The sensor board and IRIS mote is place in a waterproof box to ensure the circuit is safe from any contamination and disturbance. For hole is provided on the casing for any additional sensors to be connected. The casing and the position of the sensor on the slope model are as shown as in Figure 43 and Figure 44.

Figure 43: Sensors are plant at the middle of the slope

Figure 44: IRIS and MDA300 board is placed in waterproof container

To replicate the water absorption and flow process, water is pour from tab to the slope model for some times. While the water is pour, the reading of the sensor is constantly observed to monitor the changes of the reading as the soil become wet. The result from the moisture sensor (ADC0) and Force-sensing Resistance are shows in Figure 45.

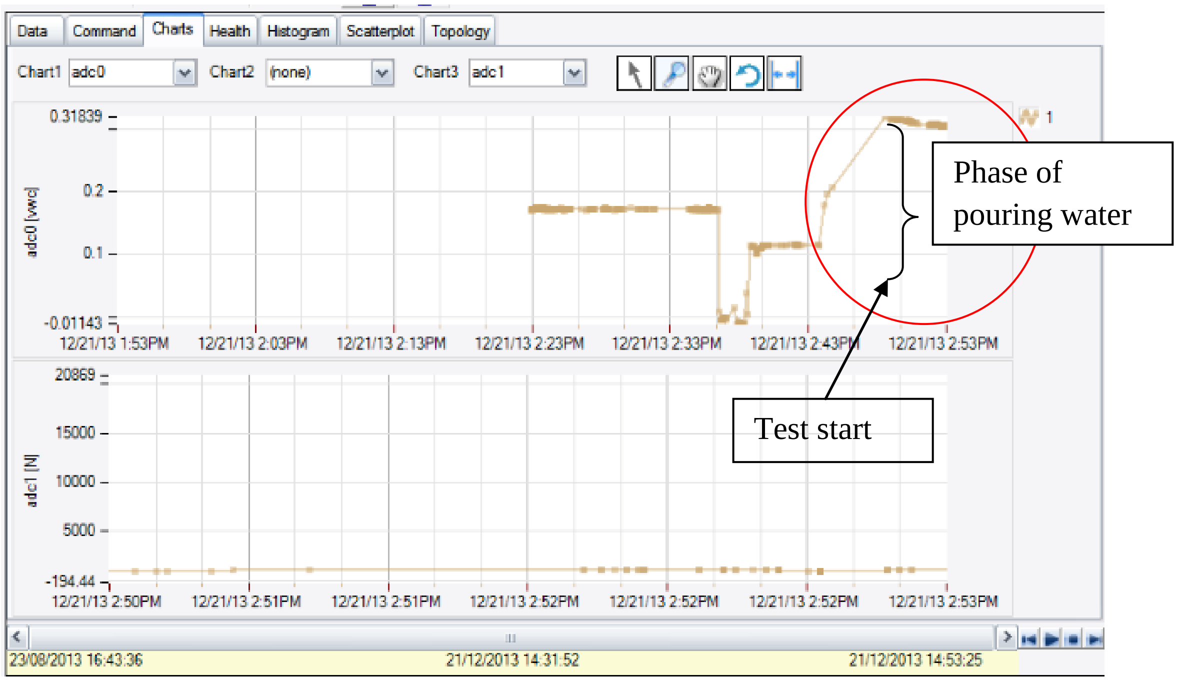


Figure 45: Test Result

In Figure 41, the VMC consistently increase while the water is pour on the slope model. Somehow the alert is not yet triggered due to the volumetric water content did not achieved 0.35 as set in the alert manager. This is due to high porosity of the slope sample which made the water seepage occurred in fast speed plus, it is a disturbed sample which made by hand. Nevertheless, the increment in reading has proved the responsiveness of the moisture sensor in the system.

For FSR, there is no significant reading shown due to testing limitation. As the purpose of the sensor is to indicate any force exerted, the job ca not be done due to the state of the soil at the high porosity level and lots of hole produce inside the hole as it is not compact compared to the real slope. As result the landslide replication happen in form of sedimentation. As the FSR is plant vertically, the force occur parallel to the surface which made the sensor provide a small change in reading value. The end form of the slope is as shown below Figure 46.

Figure 46: Sedimentation occur due to high porosity

As the limit of the alert set in the alert manager for VMC is 0.35VMC and for FSR is when the reading reach to 0.5V the warning alert is popped out stating the state of the data received. The sample of the pop-out windows is as shown as follow in Figure 47. The states of readings are as shown in the red circle.

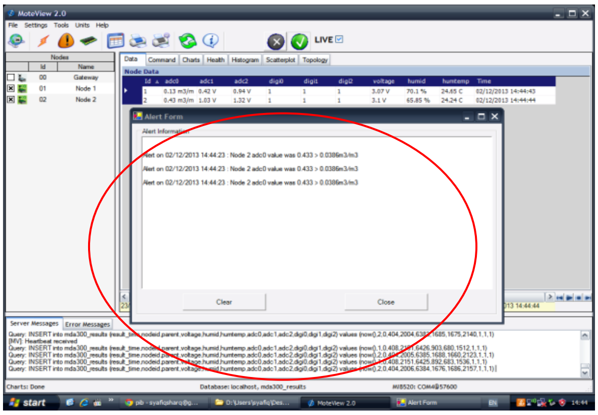


Figure 47: Alert windows

5. Recommendation

As part of recommendation, there are lots of sensor can be integrated using the wireless sensor board MDA 300, by utilizing the channel input. The board also offering digital and counter input to perform data acquisition. In this project, two sensors are unable to be integrated to the system due to cost limitation and configuration problem. There is still hope to integrate the sensors to increase the effectiveness in monitoring processes. Plus, the alert mechanism can be enhanced by using the relay channel on the MDA 300 board for site station alert rather than only having the alert at the base station using pop-up windows.

6. Conclusion

This report has include landslide introduction, status quo around the world and Malaysia, factors triggering, existed invention to monitor the landslide risk and activities and suggestion toward solving the current issues and problem facing due to landslide risk. The lack of technology, price and the limited source of sensing the triggering factors has made this project significant to proceed as it has becoming a demand to have a very reliable sensing technology, which are cheap in price, easily use and install beside offering real-time monitoring plus, less need of maintenance in operation. By integrating several sensors to monitor the physical factor such as, pore-water pressure, moisture and soil movement will helps much on indicating the possibility of landslide occurrence. As progressed, project activities have covered some of the important aspect on measurement and sensing mechanism for the chosen factors. Result and discussion are included in this progress report to provide the preview on the work has done and future work to work on.

7. References

[1] O. Hungr, R. Fell, R. Couture, and E. Eberhardt, *Landslide risk management*: Taylor & Francis, 2010.

[2] D. o. S. Engineering, *National Slope Master Plan 2009-2023*. Kuala Lumpur, Malaysia, 2009.

[3] M. Budhu, *Soil Mechanics and Foundation (2nd Ed)*, 2 ed. Hobeken: Wiley&Sons,Inc., 2007.

[4] K. Sassa and P. Canuti, *Landslides-disaster risk reduction*: Springer, 2008.

[5] S. Lacasse and F. Nadim, "Landslide risk assessment and mitigation strategy," in *Landslides–Disaster Risk Reduction*, ed: Springer, 2009, pp. 31-61.

[6] R. Shaw, Y. Takeuchi, and B. Rouhban, "Education, capacity building and public awareness for disaster reduction," in *Landslides–Disaster Risk Reduction*, ed: Springer, 2009, pp. 499-515.

[7] S.-S. Gue and S.-Y. Wong, "Slope engineering design and construction practice in Malaysia," in *CIE-IEM Joint Seminar on Geotechnical Engineering*, 2009, pp. 26-27.

[8] M. Larsen, G. Wieczorek, L. Eaton, and H. Torres-Sierra, "Natural hazards on alluvial fans: the debris flow and flash flood disaster of December 1999, Vargas state, Venezuela," in *Proceeding of Sixth Caribbean Islands Water Resources Congress, Feb. 21-23, 2001, Mayaguez, Puerto Rico*, 2001.

[9] M. V. Ramesh, S. Kumar, and P. V. Rangan, "Wireless sensor network for landslide detection," in *The Proceedings of the 2009 International Conference on Wireless Networks (ICWN 2009)*, 2009, pp. 89-95.

[10] G. See-Sew and Y.-C. Tan, "Landslides: Abuses of the Prescriptive Method," 2006.

[11] S. Qasim, I. Harahap, and S. Osman, "Causal Factors of Malaysian Landslides: A Narrative Study," 2013.

[12] L. Picarelli, "Understanding to Predict," in *Landslides–Disaster Risk Reduction*, ed: Springer, 2009, pp. 63-88.

[13] L. Picarelli, F. Oboni, S. Evans, G. Mostyn, and R. Fell, "Hazard characterization and quantification," *Landslide Risk Management,* pp. 27-62, 2005.

[14] M. T. Lowani, "Control of Ground Water for Slope Stability by Trenching Method," Civil Engineering, Universiti Teknologi PETRONAS, Perak, 2009.

[15] S.-S. Gue, D. Karnawati, and S.-Y. Wong, "Policy and Institutional Framework for Landslide Mitigation and Risk Reduction," in *World Landslide Forum 2008, Japan.*, 2008.

[16] H. A. W. M. Al-Musawi, " The Use of GIS and Resistivity Imaging Technique To Determine Landslide Probability Based Oninternal and External Causal Factors," PhD, Geophysics, Universiti Sains Malaysia, Malaysia, 2010.

[17] F. Nadim, H. Einstein, and W. Roberds, "Probabilistic stability analysis for individual slopes in soil and rock," *Landslide risk management,* pp. 63-98, 2005.

[18] G. Wang and K. Sassa, "Pore-pressure generation and movement of rainfall-induced landslides: effects of grain size and fine-particle content," *Engineering geology,* vol. 69, pp. 109-125, 2003.

[19] M. H. Heibaum and H.-J. Köhler, "Excess Pore Water Pressure and Slope Stability."

[20] H. PERSSON, "Estimation of pore pressure levels in slope stability calculations."

[21] R. C. Viesca, "The near and far of pore pressure during landslide and earthquake ruptures," 2011.

[22] R. P. Orense, S. Shimoma, K. Maeda, and I. Towhata, "Instrumented model slope failure due to water seepage," *Journal of Natural Disaster Science,* vol. 26, pp. 15-26, 2004.

[23] R. M. Iverson, "Landslide triggering by rain infiltration," *Water Resources Research,* vol. 36, pp. 1897-1910, 2000.

[24] K. Kazuo, J. Jorgen, T. Shigeki, and I. Takaaki, "Huge landslides caused by massive earthquakes and long-lasting geotechnical risks," in *Landslides–Disaster Risk Reduction*, ed: Springer, 2009, pp. 159-176.

[25] U. Third and S. E. N. Oscillations, "World Conference on Earthquake Engineering," *Engineering Structures,* vol. 18, pp. 741-742, 1996.

[26] M. E. Popescu and K. Sasahara, *Engineering measures for landslide disaster mitigation*: Springer, 2009.

[27] M. Johnson, M. Healy, P. van de Ven, M. J. Hayes, J. Nelson, T. Newe*, et al.*, "A comparative review of wireless sensor network mote technologies," in *Sensors, 2009 IEEE*, 2009, pp. 1439-1442.

8. Appendix

7.1 Appendix 1

<u>Experiment title: Volumetric water content versus sensor output.</u>

Objective: To measure volumetric water content relation with EC-5 moisture sensor output

Apparatus/material:

1. Decagon EC-5 moisture sensor probe
2. PC
3. IRIS board (base station & sensor node)
4. MDA300 sensor board
5. Soil (clay & sandy type)
6. Oven
7. Weighing scale
8. Measuring cylinder
9. Specimen tray

Procedure:

1. Prepare 2 type of soil and dry in the oven for 24 hours.
2. Setup base station for data acquisition, MDA300 sensor board and EC-5 Moisture sensor.
3. Measure the sensor output with dry sample and record the data
4. Mix both sample with 200ml of water and measure the sensor output and record the data.
5. Collect sample of both soil and put it in different specimen tray and weight it. Record the data taken.
6. Repeat number 4 and 5 with additional 200ml of water for 4 round.
7. Dry the sample taken in the oven for 24 hours and weight the dry sample.
8. Compare the different of weight and tabulate the data as shown in figure below.
9. Plot graph and obtain best straight line fits.

Formula:

Volumetric water content (VMC) $\theta = \frac{different\ in\ mass}{mass\ of\ wet\ sample}$

Table:

Sample Number	1	2	3	4	5
Mass of Moist Soil (g)					
Mass of Dry Soil (g)					
Mass (g) Volume (cm3) of Water					
Sample Volume					
VWC					
Avg Reading (mV)					

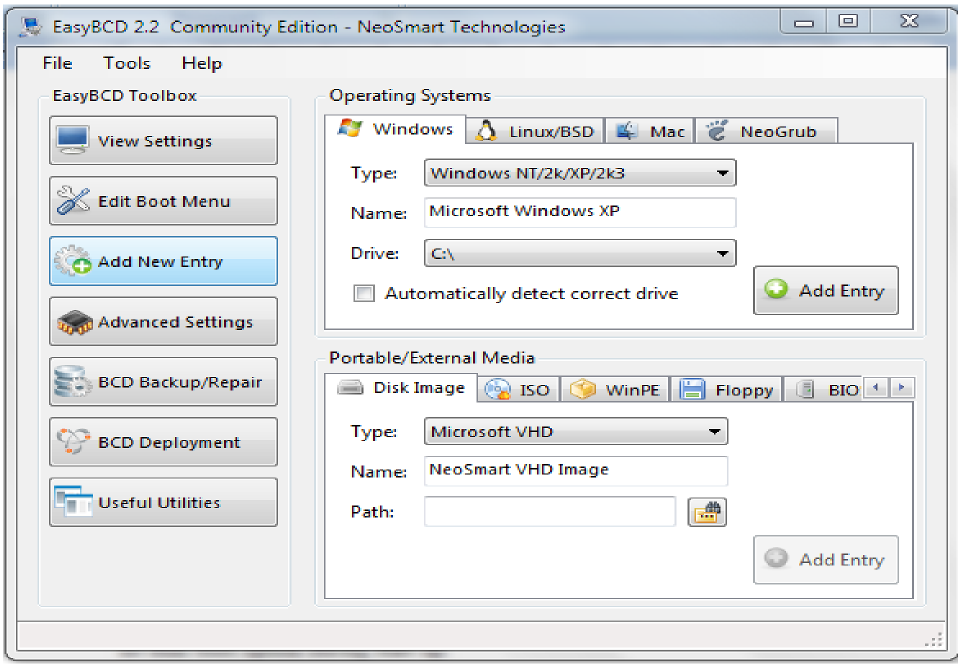
7.2 Appendix 2

➢ Dual boot windows installation guide

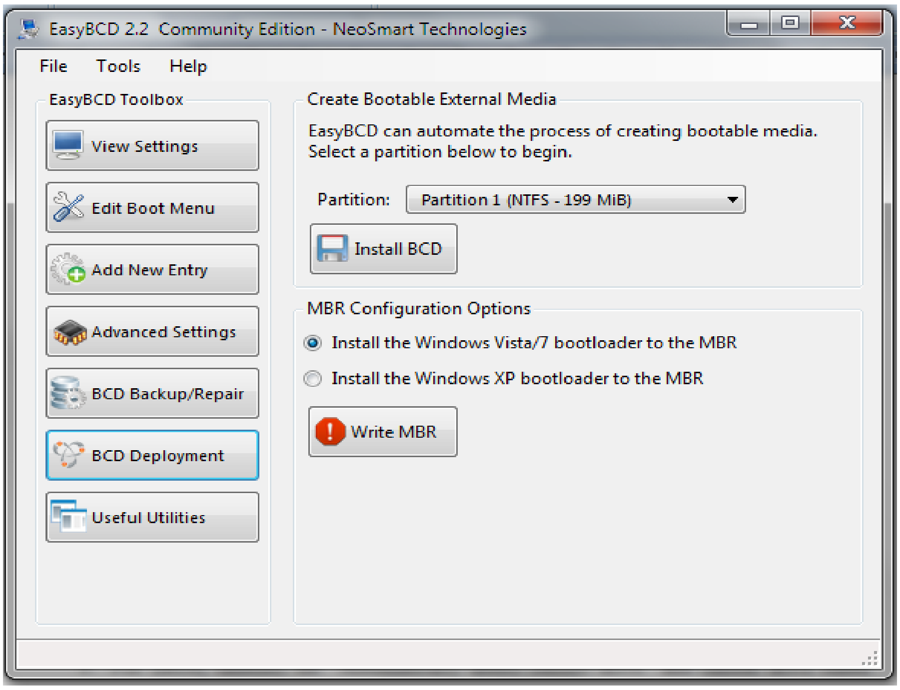
For PC with windows 7 or windows 8 running, there is no need of formatting the hard drive and install Windows XP alone. Dual boot option gives advantage to user to install both windows which can run 1 Windows at one time based on user need.

1. For installation, make sure you have enough hard disk space with separate partition, for XP small portion of hard drive is needed, for data safety and performance ensure partition for XP Windows is more than 10Gigabytes. The more the better. This action of separating the partition can be done in disk management is system tools.
2. As the partition for XP Windows is already allocated. Restart PC and enter the BIOS setup and insert XP installation software disk in compact disk drive. Then installed windows XP in desired partition. Careful while choosing disk partition as you might wrongly select the Windows 7 partition which will result all data lost due to formatting process for Windows XP installation.
3. When the installation of Windows XP is done, let the windows RUN for update and any firmware installation.
4. Note that Windows XP will overwrite the boot set up as you restart the PC. It will automatically choose Windows XP as default Operating System. To encounter this, go back to Bios set-up, and insert Windows 7 installation software and install the the existed Windows 7 partition. Be reminded this installation is not to replace the existed Windows 7 in the partition but to repair the Windows. Choose repair function when the option to repair comes out.
5. For successful repair, windows 7 will now run as default windows. Yet, still there is no dual boot option during start up.
6. A freeware EasyBCD2.2 is available on9 to solve this matter. Download and install the software.
7. Run the software and select “Add New Entry” to add Windows XP in the boot loader.

8. Set as shown below



9. For Drive, unselect the "Automatically detect correct drive" and choose drive based on partition where windows XP is installed. The click "Add Entry".
10. Then, go for "BCD Deployment" and select "install Windows XP boot loader to the MBR. Then click "Write MBR"



11. Close the application and try to restart your PC. You should be able to get dual boot windows option and give you the authority to choose which windows you desired.
12. If the problem unsolved. Get on-line help.