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Installing the earth station of Ka-band satellite frequency in Malaysia: conceptual framework for site decision

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Abstract. This paper developed a conceptual framework in determining the suitable location in installing the earth station for Ka-band satellite communication in Malaysia. This current evolution of high throughput satellites experienced major challenge due to Malaysian climate. Because Ka-band frequency is highly attenuated by the rainfall; it is an enormous challenge to define the most appropriate site for the static communication. Site diversity, a measure to anticipate this conflict by choosing less attenuated region and geographically change the transmission strategy on season basis require accurate spatio-temporal information on the geographical, environmental and hydro-climatology at local scale. Prior to that request, this study developed a conceptual framework to cater the needs. By using the digital spatial data, acquired from site measurement and remote sensing, the proposed framework applied a multiple criteria analysis to perform the tasks of site selection. With the advancement of high resolution remotely sensed data, site determination can be conducted as in Malaysia; accommodating a new, fast, and effective satellite communication. The output of this study is one of the pioneer contributions to create a high tech-society.

1. Introduction

The evolution of broadcast satellites using Ka-band frequency instead of the existing Ku-band is an emerging trend towards faster, cheaper, and efficient communication. This is because the new mode of high throughput satellites using Ka-band allowed extensive frequency reuse enabled larger amount of bandwidth support for higher transmission rates, and utilization of smaller but efficient antennas [1,2]. This advancement qualities would be strategic in addressing the growing needs of the increasing population and economy of Malaysia (~30 million, [3]); one of the rapidly developing semi industrial-agriculture country in Southeast Asia. However, the major drawback of this Ka-band in this region is their strong attenuation effects from large size water droplet of rainfall from atmospheric to ground.

Scientifically, the increasing frequency of Ka-band (26 – 40 GHz) would increase the speed of signal transmission and shortened the wavelength. The aftermath of this condition in humid tropics is the limitation to penetrate over intense rainfall with larger water droplets [4]. Literature has shown that the diameter of the rainfall in the tropics is relatively larger [5,6]. One of the effective strategy to overcome this constraint is via site diversity; selecting the area with less rainfall for satellite communication and diversifying the selection according to the local-scale wet seasons [7]. In Malaysian context, it is wise to decide based on a fine resolution of climatology data due to its high dynamic climatological pattern [8]. In addition, we also should consider the environmental aspect of the sites, its logistics and strategic condition.

Achieving both objectives can be materialized with the availability of the innovated climatology products and usage of Geographical Information System (GIS). A proper conceptual framework would be a pioneer effort in promoting this potential technology to a local scene. The design conceptual framework should be adhered a right product, approach and results which fit the local scale environmental and climatology characteristics. This study tends to occupy that effort by developing the conceptual framework based on integrated satellite-improved climatology input data that operated on GIS environment.

2. Dealing with the attenuation factors by hydro-climatology factors in Peninsular Malaysia

Peninsular Malaysia categorized as humid tropical region with perature of 26° Celcius throughout the year and annual rainfall of 2500mm. With no dry season, the hydro-climatology is driven by monsoon flows. The northeast monsoon (Nov.-Jan.) constitutes the heaviest rainfall especially to the east part (200-500mm/month). The southwest and inter-monsoon period (Jul.-Oct.) resulted second heavy rainfall which concentrated on the west region. Added the effect from high elevation areas of the Titiwangsa fringe, the local rainfall pattern can be highly heterogeneous especially during the non-monsoon season [9] (Figure 1).

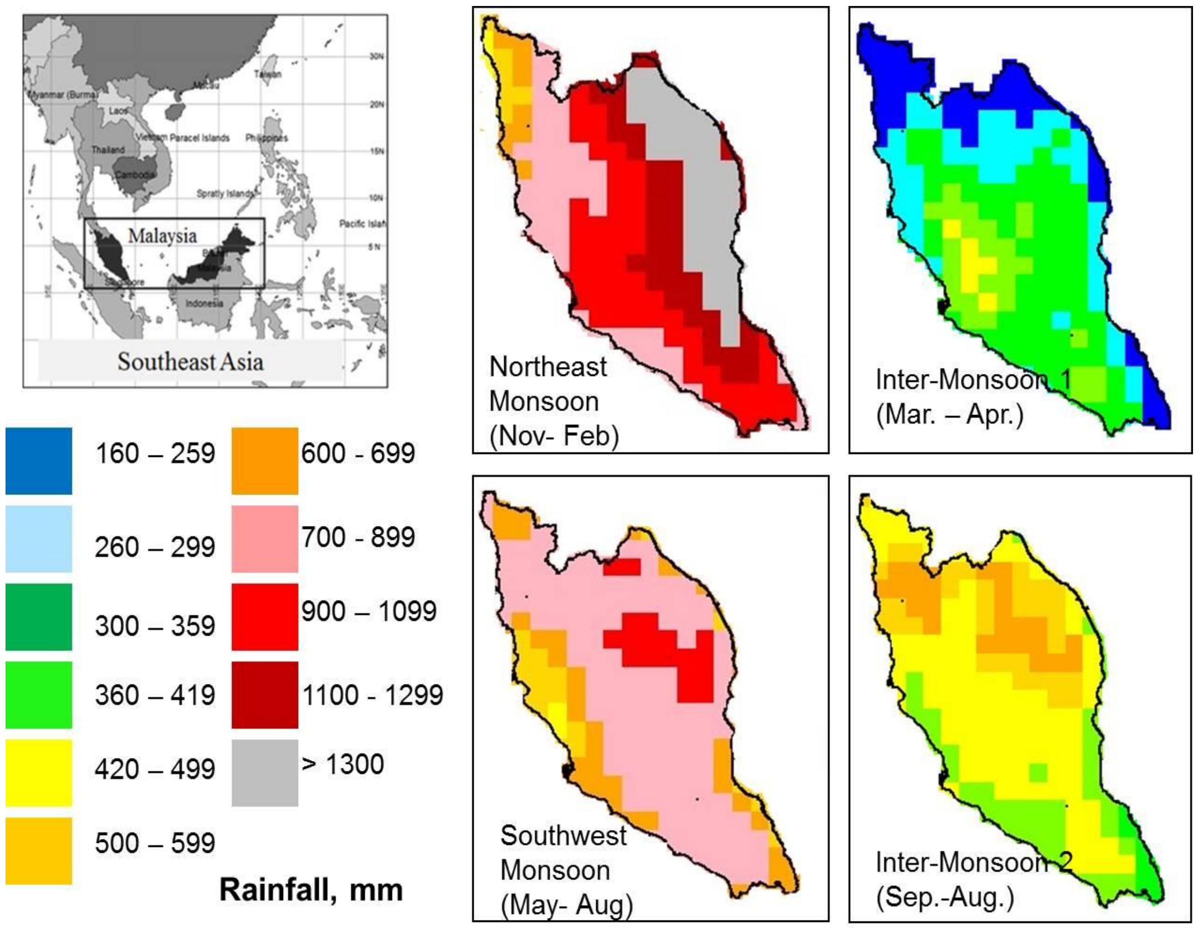

Figure 1. Peninsular Malaysia and its seasonal rainfall variation

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Due to this humid tropics and dynamic monsoon seasons; the attenuation of Ka-band frequency not only come from rain, but also the precipitable water in the atmosphere [10]. Considering the sky-free condition is depending on seasonality of monsoon flows, the wise option is to employ a selection with seasonal weightage. This can only be materialized by using high resolution hydro-climatology data; which now available to be obtained from satellites and publicly accessed.

3. High resolution of satellite hydro-climatology data & geographic computing

The advancement of remote sensor, retrieval algorithm and data sharing has significantly improved the representation of hydro-meteorological variables at both local and global scale. The high availability of such data especially one from microwave scanning [11,12] provides a perfect opportunities to tropical region, where large vapors converged, cloud formed, and rainfall downpours were indicated; a useful option to our framework.

Integration of those data with series of logical condition, programmed by geographic computing or GIS, enabled us to precisely determine the appropriate site. Given that all the data were correctly projected and the resolution is fine enough, successful data manipulation can be obtained. Those two criteria is our core to this conceptual framework.

4. Conceptual framework for site selection

The developed conceptual framework emphasize the following logic in sequential manner; (a) rainfall, precipitable water, & water vapor effects to Ka-band frequency, (b) sensitive areas which restricted for developments, and (c) strategic and logistics factors. Figure 2 summarized the design framework.

This conceptual framework utilized spatial-based decision making, where the site would be determine as multi-criteria analysis, followed the design condition in Table 1. A geographical information system usage is optimized where all the queries, display, analysis and storage of large databases, were implemented.

The pixels which fit the design condition will be given a higher score and vice versa. This method is chosen because it is relative; so relative description is the best option. At the end of the process (a), (b), and (c), is the map with selected pixels with different score; how suitable is the pixels for the earth station installation.

4.1 Attenuation from rainfall, precipitable water, & water vapor

For the first conditions, the primary goal is to determine the attenuation level contributed by rainfall, precipitable water, & water vapor. Because of the dominant effects of monsoon flows, it is best to quantify it temporally according to the monsoon season. Regarding the attenuation model, the utilization of the approach from International Telecommunication Union (ITU) was recommended. The following attenuation computation procedures for rain, cloud and water vapor from [13], [14], and [15] respectively can be utilized. This is to ensure that the attenuation was computed following the standard operation procedures.

The input of this part should be able to represent an effective spatio-temporal dimension to represent its corresponding subject of interest; at least ~5km grid. For rainfall, input from dense rain gauge network should be the first priority. Substitute or support information from other apparatus, such as precipitation radar or satellites can be considered. For precipitable water and water vapor, an input from the atmospheric & meteorological satellites or fine climatological model is the best option. In measuring total column of precipitable water and vapor, among the data that fit our objective are from The Special Sensor Microwave Imager (SSM/I), Special Sensor Microwave Imager Sounder (SSMI), TRMM Microwave Imager (TMI), The Advanced Microwave Scanning Radiometer (AMSR) or from the web-host that supply integrated products from various satellites such as the operational Microwave Integrated Retrieval System (MIRS) and the Morphed Integrated Microwave Imagery (MIMIC) (16).

In term of frequency selection, because the effective frequency Ka-band (~26-40 GHz) in tropical region is varies via location [17], selecting samples according to the constant interval is suggested.

After the attenuation rates for each parameter were obtained, the areas which have higher attenuation is ranked low and vice versa. In addition, the Ka-band attenuation effects were strongly influenced by larger water droplets, therefore, it is suggested that the weightage is assign to give emphasis in the following orders; rain, precipitable water, and vapor.

Table 1. Summary of the input, condition and ranking system of the developed conceptual framework

Phase	Input	Condition	Ranks				
			1	2	3	4	5
			Least suitable	Moderately suitable	Fairly suitable	Suitable	Most suitable
Phase 1 - Attenuation from rainfall, precipitable water & atmospheric water vapor	Monthly maps: Rainfall Precipitable water Water vapor Attenuation model: Attenuation co-efficient Viewing angle Selective frequency from 26-40GHz	Attenuation rate	Maximum attenuation rate ----> Minimum attenuation rate				
Phase 2 - Sensitive areas restriction	(i) Natural Protected areas - Forest reserve maps	Boolean logic, Yes or No	No		-		Yes
	(ii) Natural Sensitive areas - Rivers, swamp, and peatland	Boolean logic, Yes or No	No		-		Yes
	(iii) Private entities - Building, roads, expressways, railways	Boolean logic, Yes or No	No		-		Yes
Phase 3 - Strategic & logistics	High resolution aerial images	Non-occupied land	No		-		Yes
		Non-residential areas	No		-		Yes
		Appropriate slope	No		-		Yes
		Accessible	No		-		Yes

4.2 Sensitive areas restriction
The output from the attenuation rate will undergo further screening of sensitive areas. In Malaysia context, environmental sensitive areas were divided into three broad category, (i) natural protected areas, (ii) private entities, and (iii) natural reserve areas. Development or commercialization of these areas were prohibited by law and also destabilizing the ecosystem.

Environmental sensitive and protected areas include forest reserve; both inland and mangrove, and their corresponding adjacent areas (depending on context). Next, the natural reserve areas are natural features which not gazette as protected by law but contribute major services for ecosystem; rivers, swamp, peatland and their buffers. For private entities, accounted features are major road and expressways, railways, power grid & transmission areas, and private land or building.

To conduct this analysis, maps of land use, transportation, utilities and sensitive areas are used. Areas which located in this sensitive condition are excluded from the selection. A series of Boolean logic is applied for the operation.

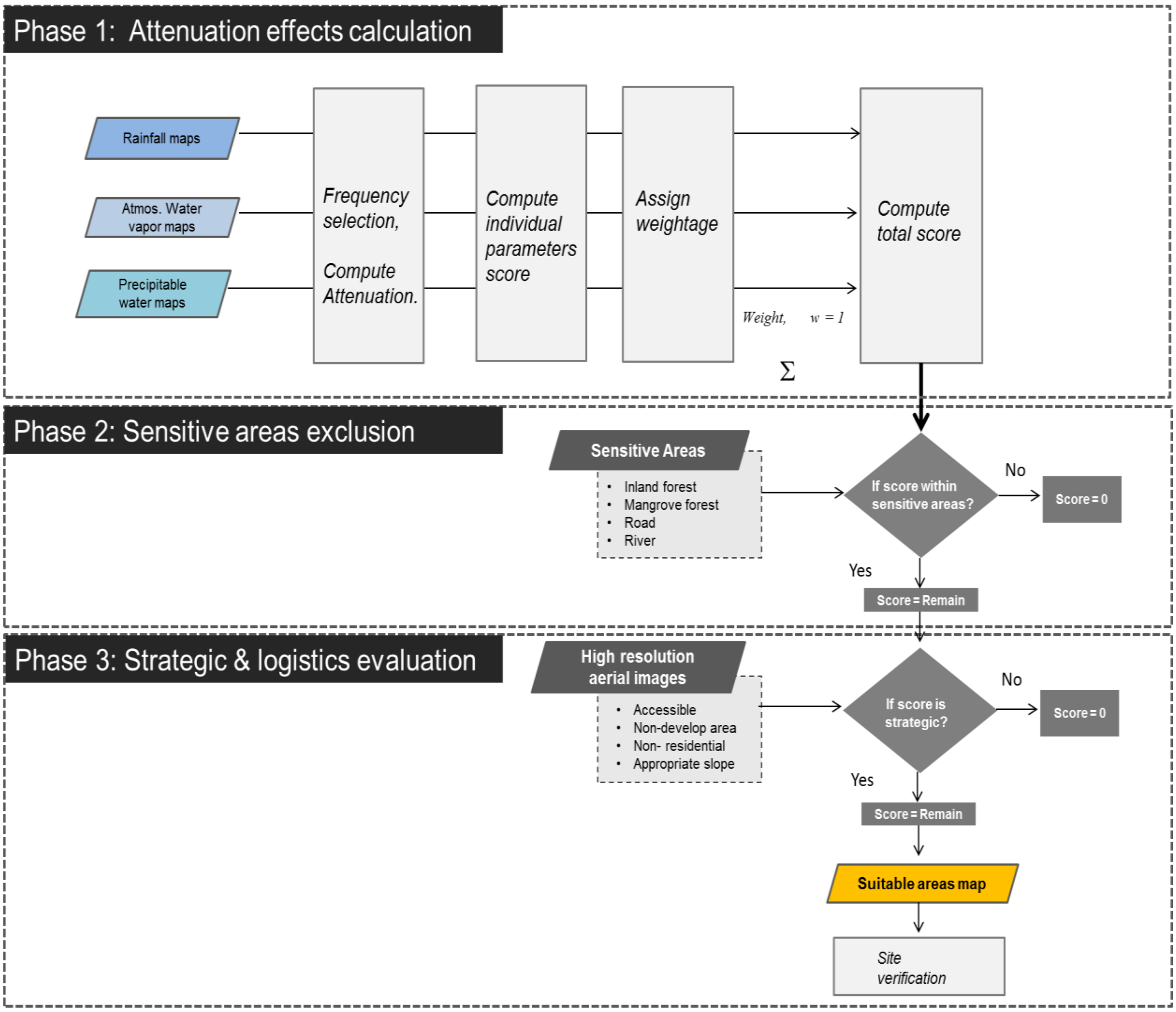

Figure 2. Conceptual framework

4.3 Strategic & logistics factors

The third phase of the framework is determining the strategic & logistics factors. This factor represents the elements which associated with the logistics aspect the earth station. That includes non-occupied land, non-residential areas, low to middle topographic slope and logistically accessible via vehicles (~200-300m).

A high resolution images are utilized. Basic filtering started with separation between densely built up areas and vegetated and non-developed areas. The use of vegetation indices is encouraged for fast processing. There are wide array of data selection for this process; depending on the quality of the desired output and cost. A low altitude and small unmanned vehicle or an aircraft with high resolution cameras can obtain the most precise resolution (1-2 meter). Meanwhile, high resolution data from satellite can offered between 10m – 15m accuracy results.

5. Conclusion

This paper developed a conceptual framework in precise determination of the suitable location for the earth station of Ka-band frequency signal. The conceptual framework emphasized the Ka-band ability to obtain effective transmission in high resolution area scale (~1km); with considering the attenuated by water droplets from rainfall, cloud and atmospheric water vapor. The site selection then being conducted using high resolution satellite imageries to potentially identify the non-sensitive areas, strategic location, meets the logistics demand and targeted community. The realization of the conceptual framework would be the pioneer step in creating fast, efficient and cheaper network from the high throughput satellites.

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