

A Case for Involving Environmental Conditions In Characterizing the Radio Space In Ghana

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Abstract – Advances in wireless technology have made it one of the major ingredients that all emerging nations seek to incorporate in their recipes for economic development. Acquisition of current technologies have to be made with serious consideration being given to their impact on both urban and rural populations, and economies in developing nations like Ghana. This raises the issue of cost. On this basis, the up-front money needed for installation and commissioning, has to be balanced with the tariff from purchase as a service, and revenue from use. Also this has to be assessed in terms of the environment considering deployment. The environment directly influences the ambient conditions that will impact operational conditions of the technology. Such factors make it necessary to provide the technicians, technologists, and engineers with the necessary skills to operate and maintain the equipment. University and college faculty members and students conduct research on the influence of the environment to gain knowledge that may pertain to their specific radio space with the view to better understand how they may undertake their roles in supporting industry. The on-going studies being done also covers cost analysis to provide insight to decision and policy makers to aid their functions. This paper presents the incorporation of environmental conditions in a course, and a thoughtful approach used to select research topics that will lead to collaborative learning among the research students to help prepare them for the wireless industry upon graduation.

Keywords – *Research Training; Curriculum Design; Environmental Conditions; Collaborative Learning; Wireless Applications*

I. INTRODUCTION

Ghana is situated well within the Tropic of Cancer, where the tropical climate is hot and moist throughout the year [1]. This region is characterized by torrential rainfalls during the wet season, and hot dry weather the rest of the year. Its geographical position is between 4° North and 12° North of the equator [2]. The south of Ghana is bound by the Atlantic Ocean, and to the north is Burkina Faso. The rain forest stretches about 225 kilometers north from the shore; within this area there is torrential rainfall during the wet season. This results in heavy vegetation growth over stretches of the land. Beyond this is dry arid land up to the northern border [3] where intense heat occurs. The heat causes any rainfall in this region to quickly evaporate. The average temperature in this region ranges from 72°F to 104°F and the rainfall rate is between 0.3 centimeters to 22.6 centimeters [4, 5, 6, 7]. In this region, evaporation from the soil and water bodies, and transpiration from plants, evapotranspiration, is high [3] and has higher incidence of dust than the southern region. The closeness to the ocean and therefore the ocean spray, the rainfall rates, the lush vegetation, and the temperature variations depict the environmental conditions experienced in the radio space of Ghana. Information transmission, and exchange have become the currency of the modern world, and this is being pursued vigorously by the developed nations. This process is not lost on developing nations, and that is the status of Ghana. The technology of choice for the information age is information and communication transmission (ICT), and developing countries are emulating the good practices that have proved successful for developed nations. The delivery of ICT can be either by wire or wireless. It must be stated though, that wireless systems are usually hybrid, having some components that are wired. Ghana intends using ICT to support its diverse development agendas. Two of the objectives for the development of ICT in the public sector is to create *e-Governance* [8] which will rely on information flow between the government and the people of Ghana, and *e-Health* which will involve information exchange between health care practitioners and their patients [9]. ICT can therefore be viewed as having a positive impact on human welfare [8]. Important as these may be for the development of the nation, if both urban and rural areas are all involved in the use of the developed systems, there are problems that need to be overcome, not the least of which is the upfront cost of development. Even so, the government of Ghana is making efforts in deploying these applications, considering the benefits that the people of Ghana will gain. For a sustainable program, the technicians, technologists, and engineers who will operate and maintain the system need to be provided the skills required to function in the ICT environment effectively. There is therefore a part that educational institutions have to play to support the mission and goals of the government of Ghana in this endeavor.

II. INDUSTRY PERSPECTIVE

To validate the choices of course content made by educational institutions to support the technological development in Ghana, it is important to review the trends that are leading to the current requirements. To do so, one must consider technical deployment in urban, and rural areas. Technology penetration in rural areas in Ghana is generally minimal. Radio and TV may be possible in areas where there is electrical connectivity to the national grid. Most rural areas do not have this utility. Use of cell phones is however possible in cases where the coverage area of the provider extends over the area. This however is minimal in the sense that rural areas close to urban centers may have the service. The ability to purchase the service is a major problem for most residents in such areas because the average wage is barely enough to feed themselves and take care of children's tuition fees [10]. Wireless is the dominant application in such cases where affordability and access is minimal. Affordability and access is higher in urban areas, but because of the influx of people from rural areas to urban areas in search of profitable employment, the high population numbers do not translate to high numbers in use of the services. The per capita GDP in Ghana is a little over US\$4 and the cost of various services is a challenge [9]. These challenges have not deterred the government of Ghana from investing in an infrastructure for information and communications technology for accelerated development (ICT4AD) [9]. In introducing F. Mekuria's article [10], the Editor in Chief of ComSoc Technology News (CTN), A. Gatherer, pondered the possibility of losing the next billion mobile/wireless users with respect to the deployment and application of the next generation wireless, the 5th generation. His concern was in relation to African users. In responding to this question, F. Mekuria pointed out that the dominant application in Africa is the 2G [10], and that 4G is inconsistently available at a high cost in urban centers. Underlying this scenario is the cost involved in construction of the system, and the cost in buying the service. He argues that multinationals who provide these services base their criteria for investment on economies and "short-term" profit margins. His position is that Africa and emerging economy countries would benefit from affordable broadband internet connectivity which will result in improvement in sectors such as education, health, and agriculture. Broadband Internet service can be by digital subscriber line (DSL), fiber, cable, or wireless. This will in turn attract investment for business and industrialization. The expectation is that coverage of the service will include both urban and rural areas. With the hope of not missing out the many possible users from Africa and the emerging economy nations, Alan Gatherer suggests that ultra-low cost broadband (ULCBB) may be considered in writing the standard for 5G. As stated above, academic institutions in African and emerging economy countries have a role to play in supporting the development programs of their respective nations, and this direction in technological development is one area in which to contribute.

III. ACADEMIC PERSPECTIVE

The foregoing emphasize the appropriateness of academic institutions engaging in skills training that will provide the needed technicians, technologists, and engineers who will operate and maintain the developed systems. As the government is investing in the infrastructure, it is equally important to invest in promoting, and upgrading the knowledge base to support sustainability of employment for the technology. As discussed in [9], technological progress requires skills upgrading through explicit learning which educational institutions are designed to provide. In Ghana where provision of this level of technology is relatively new, it will be necessary to plan this process with care. There is the need for practice in acquiring the knowledge while at university/college, to be supplemented with industrial experience to ensure proficiency in the skillset required in working with the technology. To cite an example, the e-Governance Network Infrastructure in Ghana is being constructed by Huawei Technologies (GH) SA Ltd [11]. It is within reason to arrange student placement with the company while still in university to help them correlate practice with theory. The academic work can be classed in two categories, these being the hardware aspect that will perform activities such as modulation, multiplexing, and transmission, and the second to focus on transmission through the radio space. This paper focusses on propagation through the radio space in Ghana, and the effects of attenuation that can occur. This is discussed in a course in Wireless Communication Networks taken by students in a Master in Telecommunication Engineering program at Kwame Nkrumah University of Science and Technology (KNUST) in Kumasi, Ghana [12].

IV. SOURCES OF ATTENUATION

The nature of the atmosphere leads to attenuation considering the impedance of free space and the fact that this is determined as the square root of the ratio of permeability and permittivity of free space. For this matter, the aerosol particulates that are found in the radio space are discussed. Path loss is also an important parameter but it is discussed extensively in the literature [13, 14], and does not form part of the discussion in this paper though it is discussed in class.

As stated above, Ghana is situated within the Tropic of Cancer and the southern part which is about a distance of 225 kilometers from the shore experiences tropical rainfall during the rainy season that can be heavy. Rainfall is one of the environmental elements that causes attenuation in electromagnetic propagation [15]. The discussion is structured to present rain as one of the factors in the analytical process in conducting research in the design of communications systems. Rain forms one of the parameters in formulating equations to be used for simulation.

Rainfall has varying rates described as light, moderate, heavy, and extreme rain [16]. All the rates mentioned above are experienced in the tropical zone. These rates relate to the shapes of the drops as they fall [17]. Raindrops of radius less than 1 mm are spherical. Larger rain drops of radius around 2 mm and 3 mm assume the shape of “hamburger bun”. Drops with radius larger than 4.5 mm are deformed into the shape of a parachute and eventually break up into smaller drops. , raindrops of radius less than 1 mm are spherical. The various shapes and deformations are attributed to air pressure pushing up against the bottom of the drops, and surface tension of the water. The wavelengths of the propagation when comparable to the sizes of the drops results in reflections, refractions and scattering [16]. A comprehensive procedure in calculating rain attenuation distribution on a microwave path is presented by S. H. Lin [18]. The environment of Ghana is not uniform, and varies from tropical to arid regions. This suggests the need to discuss effects of rain in the arid zone. A team of researchers have published a paper discussing such environment [19]. The team also state in their paper that rain fade is dependent on the frequency of transmission, and is higher at frequencies above 10 GHz. This point is also discussed with the students. The rationale is to motivate them to make careful selection of research topics. The objective in this is to get them to collaborate in sharing results and ideas since they would be working on different components of the same topic; propagation through the radio space of Ghana.

Dust

Interaction of electromagnetic radiation with dust presents a very interesting study due to its inhomogeneity. Dust particles have different mineralogical compositions and these would have different refractive indices [20]. In addition to this, dust particles have different shapes and sizes. Scattering for instance, would therefore be a phenomenon based on individual particles uniquely. Dust therefore requires attention when discussing radio propagation in Ghana. While the minerals are mostly in the southern part of Ghana, the northern border of the nation is rather close to the Sahara desert, and airborne dust particles from the Sahara can be carried into the radio space of the nation. Studies indicate that Sahara mineral dust also exhibit refractive indices [20]. This will add to the complexity of the effects of dust in the radio space of the nation.

Foliage

In discussing attenuation due to foliage, it is noted by Meng and Lee that leaves, twigs, branches, and tree trunks cause scattering, diffraction, and absorption of radiated waves [21]. The authors suggest that the effect of foliage may be discussed in terms of three distinct scenarios. These are

- a single tree,
- a line of trees, and
- a forest.

They further state that wireless sensor networks have been used to study the effects of attenuation in the forest. They suggest that among other applications, Multiple-Input-Multiple-Output (MIMO) technique requires to be studied. This is in fact one of the points that is stressed with the students, that literature reviews may lead to topics that require research. Analysis for attenuation due to foliage may be done for a horizontal path, or for a slant path. Other points raised in this paper are the effect of shadows cast by trees on an incline, and the effects of wind and rain that can cause variations in the shadows.

V. ASSESSMENT

The assessment methods that have been used thus far are provided in the list below [22].

Formative: This has been applied in the form of questions and answers – the answers give an indication of what the students have learned, and also act as feedback to highlight what points need to be covered again for clarification. Also in a way, this is diagnostic in providing feedback as the instruction is going on.

Summative: This is mainly used for end of semester evaluation.

Process: This is used specifically in checking students’ progress during the project phase. Students are required to submit each chapter of their project report as it is completed, and at the end, the whole report.

VI. CONCLUSION

The environment of a Sub-Saharan African country, Ghana, has been used as a tool to instruct students preparing to undertake the project component of their Master of Science in Telecommunication Engineering program. The course that this will be a component of is Wireless Communication Networks. The component begins with discussion of journal papers to get the students to note the format of a technical report, and the importance of the different components of an academic report. This is intended to get the students to appreciate the structure their project report should follow. Because of the nature of the course, the elements of the environment that cause attenuation to radio propagation, rain, dust, and foliage are discussed. Different elements of the component have been applied by students in their work. The students are advised to work collaboratively so that their learning may be global in their area of expertise, while they master specific components of the general area.

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