Wireless Sensor Network Wave Propagation in Vegetation

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Abstract The Wireless Sensor Network (WSN) total path losses of a greenhouse based on the two popular empirical vegetation attenuation models are used to predict the connectivity and the maximum coverage of wireless nodes within the communication path. The foliage imposed effect on the propagating waves is examined, simulated and the total path losses concluded as a function of antenna height and a separation distance of WSN nodes in a field of various densities of vegetation inside a greenhouse. The implemented library of foliage propagation model can be embedded easily with other WSN simulator platforms. The best antennas height based on greenhouse environment and total path loss is shown to be with the 3.5 m and 1 m height for transceivers of main and end nodes, where less total path loss is obtained and perfect connectivity of (100 %) when used with MED vegetation models for all vegetation depths, less than 50 m, while ITU model shows perfect connectivity for same height combination but with less foliage depth of 40 m while it shows 88 % connectivity for higher foliage depth than 40 m.

1 Introduction

Wave propagation analysis based on environmental modeling provides a good initial estimate of the signal characteristics. The ability to have an accurate prediction of radio propagation behavior of a wireless communication system, such as wireless sensor network, is becoming crucial to design scheme of a system where radio wave propagation throughout a foliage medium induces an additional excess

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loss on the propagating components such as direct and reflected waves. Therefore, to provide reliable and enhance network coverage and connectivity of WSN, a precise study and modeling of these effects must be achieved with adequate prediction of the propagation losses [1, 2, 3].

Most of the radio propagation channel models, in a simulation environment, assume an obstacle free propagation channel, and hence, a clear direct path exists between the communication nodes. Thus, in a simulation environment, the performance of wireless communication system is estimated based on those models and the results produced often poorly reflect the real scenario, such as plantation area, in which the presence of vegetation significantly affects the communication between network nodes. As recommended by Meng et al. [4], for short range near ground plantation environment, propagation loss is modeled by an integration of the foliage imposed effect and the effect from the radio wave reflections from the ground and possibly tree canopy. There are different vegetation propagation models reported in published literature [3, 5, 6] and these models are verified by numerous experimental studies in Savage et al. [7], Meng et al. [4], Morataitis et al. [8].

In this chapter, the foliage imposed effect on the propagating waves is examined, simulated and the total path losses are concluded as a function of antenna height and the separation distance of WSAN nodes in a field of various densities of vegetation inside a greenhouse. The WSAN total path losses of a Greenhouse based on the two popular empirical vegetation attenuation models, namely Weissberger Modified Exponential Decay (MED) and ITU-Recommendation (ITUR) models are modeled, simulated and analyzed to predict the connectivity and the maximum coverage of wireless nodes within the communication path. The implemented library of, foliage propagation model can be embedded easily with other WSN simulators like OMNeT++, NS-2, OPNET simulation platforms [9–11].

2 Precision Agriculture Based WSAN

Precision agriculture provides the means for monitoring, evaluating and controlling agricultural practices. It covers a wide range of agricultural trends from daily herd management through horticulture to field crop production. Continuous monitoring of individual crop and its necessities will help growers to potentially recognize a variety of fertilizers, irrigation, ventilation, climate automation and other requirements that provide optimal environment and conditions for crop growth [12]. To determine the behavior of electromagnetic waves, a precise model of propagation must be adopted, however propagation models normally used in wireless communication might not be precisely described the wireless sensor network [13]. WSAN nodes are spatially located; usually near the earth's surface thus induce absence of main ray between sender-receiver nodes, although WSAN nodes have spatially short distance distribution. Therefore, WSN propagation waves may face obstacle like trees, fence, building and dense foliage.

The newly emerged WSN technology has spread rapidly into various multidisciplinary applications. Agriculture and farming is one of the industries which have recently redirected their concentration to WSN, looking for this cost effective technology to improve its production and enhance agriculture yield standard [14]. There are several test points equipped with wireless nodes of various sensor types which they are used to collect the local climate, fertilizing and irrigation parameters within different parts of the greenhouse to provide information for successful greenhouse automation system. Cabling of sensor nodes would make the measurement system expensive and vulnerable. Furthermore, the cabled test spots are hard to relocate once they are installed. Thus, WSN is an attractive and cost competent alternative to build the required measurement system. Such as temperature, humidity, light and the carbon dioxide are the most important factors for the quality and productivity of plant growth. Hence continuous monitoring of these environmental variables gives information to the grower to better awareness, how each factor impinges on growth and how to administer maximal crop productiveness [15]. The optimal greenhouse climate adjustment can enable us to improve productivity and achieve remarkable energy savings [7].

3 Physical Aspect Challenges of Applying WSN in Agricultural Fields

Real time radio propagation in a real environment is complex due to the existing of multipath propagation, shadowing and attenuation. In the agriculture field, the wireless communication face challenges in terms of nodes location for wide area mesh coverage and reliable communication link quality above crop canopies. WSN must have the ability to work in a wide range of environments such as bare fields, orchards, vineyards from flat to complex topography and with various weather conditions, all of which affect radio performance [1, 16, 17]. In these environments and situations, the terrain, crop growth, nodes spacing, antenna height and in addition to more common factors will affect the link power budget. For applications inside buildings like greenhouses or warehouses, the radio signal has to go many objects like windows, walls, pallets, machines, which indeed cause a significant degradation in received signal strength. Mostly a 10–20 dB of a received signal level above the sensitivity threshold of the receiver is an accepted value for the link budget [18]. As the crop growth, the density of the leaves increased over time and thus message rate decreases, while when there are less leaves; the message rate increases. Signal propagation above the cross canopy results in attenuation and variance in the received signal strength [19]. Hebel shows that the attenuation and signal strength variance were dependent on line of sight losses and heights less than the Fresnel zone radius [20]. Experimentation in mature corn fields (2.5 m hight) with transceivers placed at antenna heights of 1.5 m and 2 m and a distance of 100 m, showed an average 10 dB loss when the transceivers were placed in or across the corn rows [18, 21].

4 Radio Wave Propagation Models in Simulation Tools

The propagation wave between transmit and receive antenna of a radio link is subject to a variety of effects that can alter its amplitude, phase, or frequency. Such propagation effects include; reflection from the ground or large objects, diffraction from edges and corners of terrain or buildings, scattering from foliage or other small objects, attenuation from rain or the atmosphere and Doppler effects from moving antenna.

WSNs simulators use Propagation models to calculate the path losses due to wireless channel impairment. These models are based on real measurements and represent a statistical mean or median of the expected path loss. The predicting of the average received signal power at a given distance from a transceiver node yield to estimate the wireless communication coverage and hence, the calculation of the success rate of packet reception. Despite that, most simulators assume a fix propagation distance for each node where the signal propagates exactly meters or using of free space propagation model (FSPL) or Two-Ray propagation model (T-R). Therefore, radio wave propagation must encounter the impairment of various types of obstacles found between the transceivers and hence more complicated path loss models must presented than these simple models.

Therefore, WSNs simulators need for more efficient and realistic propagation models that encounter the different effects of the environments under vision. The modeling of a common path loss model for all communication systems that take into account all various obstructions, paths, terrain and atmospheric conditions is difficult and not strategic solution. As a result, there are different models found in different types of radio wave propagation for different conditions and phenomena. For agricultural application the foliage effects will represented by the two well known foliage models MED and ITU, and the total path losses will be calculated based on fusion of foliage and FSPL, T-R path loss models.

4.1 Free Space Path Loss (FSPL)

FSPL is a wave propagation model that assumes an ideal propagation conditions along the way between transceivers, it is widely used model in simulation environments. Friis free space equation provides a prediction of the received signal strengths when the transmitter and receiver have a clear, unobstructed line of sight path between them [22, 23]. The FSPL is calculated by;

$$P_{Loss}\,\text{dB} = 32.45 + 20\log_{10}(d_{\text{km}}) + 20\,\log_{10}(f_{\text{MHz}}) \tag{1}$$

where f is the frequency in MHz and d is the distance in km between the transceivers. FSPL implies that the received power decreases with distance at a rate of 20 dB/decade. Thus, the received signal power falls off inversely proportional to the square of the distance d between the transmitter and receiver antennas.

4.2 Two-Ray Ground Reflection Model

Ray tracing is a method that uses a geometric approach, and inspects what paths the wireless radio signal follows from transmitter to receiver. Ray-tracing prediction models are good when detailed information about the area is obtainable. While the predicted results may not be applicable to other locations, thus making these models site specific. The fact that for most wireless propagation situations, two paths are found from transmitter to receiver antennas: a direct path and a reflected off the ground path. This model gives a more accurate prediction at a longer distance than the FSPL [22, 23].

Typically in WSNs, wireless sensor nodes are deployed with small elevation from the ground, nearly (0.05 m – 1 m) with low transceiver antenna heights [4]. Therefore, T-R model is a better descriptor for path loss when radio waves propagate near the ground rather than the FSPL model [23]. The T-R path loss model can be calculated by (2).

$$L_{PE}(\mathrm{dB}) = 40\log_{10}(d) - 20\log_{10}(h_t) - 20\log_{10}(h_r) \quad (2)$$

To maximize the connectivity of network nodes due to plane terrain ground reflection the antenna height must clear the first Fresnel zone [22]. The Fresnel zone radius, r in meters, can be calculated by (3).

$$r = 8.657\sqrt{\frac{d}{f}} \quad (3)$$

where, d is the separation total distance between transceivers in km and f is the frequency in GHz.

The Fresnel zone is the area which includes emitted power. Objects within this zone can cause signal degradation and power defeat from the transmitter to the receiver. The more obstacles within the Fresnel zone, the more wave reflections and phase shifts will be induced, that can lead to a loss in the received power. Moreover, as antenna height gets close to the earth's surface (as with the case of our WSN), the earth's surface goes in the Fresnel zone, making an impediment to communication [24].

5 Wave Propagation Models in Vegetation

Most terrestrial wireless communication systems may require signals to pass through the foliage at some area along its propagation path. Thus, many applications of WSNs, such as military and agricultural applications, may face the challenge of impairing the signal due to the existence of vegetation and crops. The attenuation of radio wave that propagates through vegetation region is considerable, especially at higher frequencies [5]. Many valuable research have been conducted to model these effects experimentally, most of them are formulated the attenuation as a function of foliage depth and the working frequency. However, the wide range of conditions and types of foliage makes it difficult to develop a generalized prediction procedure.

In the literature, several models to evaluate the excess attenuation due to the presence of foliage in the propagation path can be found. The majority of those models are defined by the expression of (4) [25]. In WSN for agricultural application, a well known models such as Weissberger's Modified Exponential Decay model [6] and ITU Recommendation (ITU-R) [3] is adopted in this work.

$$L_{Veg} = A \times f^{b} \times d^{c} \tag{4}$$

where L_{Veg} is the excess attenuation due to foliage, f is the working frequency and d_f is the depth of a deciduous tree in meters, A, B and C are empirically calculated constants, which are dependent on the type of foliage.

5.1 Weissberger's Model

Weissberger's Modified Exponential Decay model [6, 26, 27] is given by (5). MED model applies when there are dense, dry, leafed trees blocked the propagation path between transceiver antennas within maximum distance of 400 m. Blaunstein [2] indicates that the model covers the frequency range from 230 MHz to 95 GHz.

$$L(\text{dB}) = \begin{cases} 1.33 \times d_f^{0.588} \times f^{0.284} & 14 \le d_f \le 400 \\ 0.45 \times d_f \times f^{0.284} & 0 < d_f < 14 \end{cases} \tag{5}$$

where d_f is the depth of foliage along the LOS path in meters f is the frequency in GHz. Attenuation predicted by the vegetation propagation model is in addition to free space and any other non foliage loss.

5.2 Early ITU Vegetation Model

ITU-R model estimates the path loss encountered due to the presence of vegetation along the propagating path. It is an easily applied model that provides results that are fairly consistent with the Weissberger model. The model was proposed for cases where either the transmitter or the receiver is near to a small (d < 400 m) grove of trees such that the majority of the signal propagates through the trees. The model is represented by (6) [3].

$$L(\mathrm{dB}) = 0.2 f^{0.3} d_f^{0.6} \tag{6}$$

where *f the frequency in* MHz *is* d_f is the depth of the foliage along the LOS path in meters.

6 Total Path Loss in Vegetation

The modeling of path propagation loss of a communication channel through vegetation is the integration of foliage loss with the free space loss. The total path loss can be formulated as:

$$P_{Tot-loss} = P_{FSPL} + P_{Env-loss} \tag{7}$$

where $P_{Tot-loss}$ is the total path loss, P_{FSPL} is the FSL (T-R MODEL) and $P_{Env-loss}$ is the vegetation loss. The resulting signal power received is given by

$$P_r = P_t - P_{Tot\_loss} \tag{8}$$

While the maximum allowable path loss for WSN can be approximated by

$$\mathrm{Loss}_{\mathrm{thr}} = P_t - R_{sensitivity} \tag{9}$$

where $R_{sensitivity}$ is the receiver sensitivity, $\mathrm{Loss}_{\mathrm{thr}}$ is the maximum path loss in dB. The total path loss cannot exceed $\mathrm{Loss}_{\mathrm{thr}}$ value without violating the receiver sensitivity. Therefore, for WSN nodes being in the range of communication coverage, the separation distance d must be less than maximum propagation distance $d_{\max}$. The existence of a radio link between nodes is computed by comparing the P_r calculated using propagation model to the Receiver Sensitivity threshold ($R_{sensitivity}$). While the packet is successfully received by a receiving node if the P_r is greater than $R_{sensitivity}$ of the receiver and no other packets being sent or received. Contrarily, if P_r is less than $R_{sensitivity}$, then messages are treated as noise.

A new library (Veg_Path_Loss) of radio wave vegetation loss is built which can be integrated with simulators based C language structure. This library is used to simulate and calculate the total losses based on foliage losses of well known MED or ITU vegetation models with the FSPL and T-R propagation path loss model, also the communication coverage and network connectivity have been included and simulated results can be used to indicate the reliability and performance of the network as well as its provide a tool to investigate the configuration of node placement with respect to a connectivity issue.

7 Simulation Setup of WSAN in Agricultural Greenhouse

The simulation assumes a greenhouse of 100 m × 100 m area where sensor nodes are deterministically distributed over this area with 10 m separation distance between adjacent nodes. The total number of sensor nodes is assumed to be 100 nodes. This assumption is based on harum manis mango cultivation plan for all season in big greenhouse structure in Perlis, Malaysia. The greenhouse terrain is flat and it mainly consists of sand and soil, with grass covers some parts.

The WSN based agricultural greenhouse application is configured based star topology with the main sink node in the middle. Deployment of wireless sensor nodes in the field could be either random or deterministically based on the application. However, proper planning for deployment of network nodes is extremely important since without proper nodes locations will highly affect the network connectivity and may result in sever network performance degradation. Within greenhouse field, the WSN nodes are deployed based on a pretested of signal strength represented by link quality indicator (LQI) of sensor node within the main node, this test is helpful to guarantee that nodes is at least seen by the main node in free space environment. While the environment is changeable within time due to plantation and growth which affects the communication channel.

To achieve a successful network communication environment, network nodes must be within the communication range. Despite that, there are many scenarios to deploy the network nodes, but the most effective one is the grid based deployment which is one of the most suitable for agricultural application and especially for greenhouse environment. There are different popular pattern of grid mapping of nodes such as square grid, equilateral triangle and normal hexagon. It is seen that the square grid be most effective when a main node located in the center of the grid [28]. Therefore, the square grid mapping is adopted for network node deployment with the main node located in the center of the topology. In this simulation the IEEE 802.15.4 standard is used with operating frequency of 2.4 GHz. The WSN deployed based on non beacon enabled star topology. The wireless channel bit rate is 250 kbps. The transmission power of 0 dBm is chosen for all network nodes and the sensitivity value of −95 dBm based on Omni directional antennas with a typical gain of 1 dBi are used at in the transmitter and receiver.

The integration of free space and T-R path loss models within foliage models is simulated for different vegetation depth and also for different antenna heights. Therefore, the communication network coverage and the connectivity of the nodes within a greenhouse environment based on grid deployment of 10 m apart nodes, within main node in the center are conducted. The antenna height is experience to find the best heights configuration to ensure better link connectivity for various vegetation depths.

8 Results and Discussion

The impact of antenna height, for the transmitter and the receiver is investigated based on (2). Figure 1 shows the loss as a function of different distances of equal antenna height, as the antenna is far away from the ground, the loss is less, for comparison, antenna height of 0.5 m of a system has a path loss of 64 dB while the same system with an antenna height of 2 m has a loss of 40 dB at 20 m of distance, this reduction in loss must be considered when designing the wireless node's height so maximum height subject to applicable limits which minimize the path loss must be chosen. For application of an agricultural field, the antenna height of the transmitter may be differs in height from the receiver antenna node.

Figure 2 shows that antenna height of a transmitter is above ground by 3.5 m, while the receiver nodes antennas may vary between 0.5, 1, 1.5 or 2 m above ground level. Obviously the attenuation for such system will be higher than a system with same level antenna height (LOS), although this, some application need like this configuration and the path loss prediction computed shows that 1 m receiver antenna height is the most suitable height for agricultural application and for greenhouses specifically, the loss is 57 dB, for distance depth of 50 m among other height losses, also this height adequate the wireless sensor network application inside greenhouse.

For the agricultural applications such as greenhouse in our simulation, the foliage depth range from 1 to 48 m between farthest wireless end node and the based station node with max foliage loss of 16.68 and 21.6 dB for MED and ITU models respectively. The simulation assumes that there are 5 levels of sensor node far away from base station node, these levels is separated by 10 m apart, hence level (i) = 10, 20, 30, 40, 50 m; for i = 1, 2, 3, 4, 5. Therefore foliage depth will be in the range of $1 \le d_f \le level(i) - 1$ and the transmitter antenna height is 3.5 m while 1 m

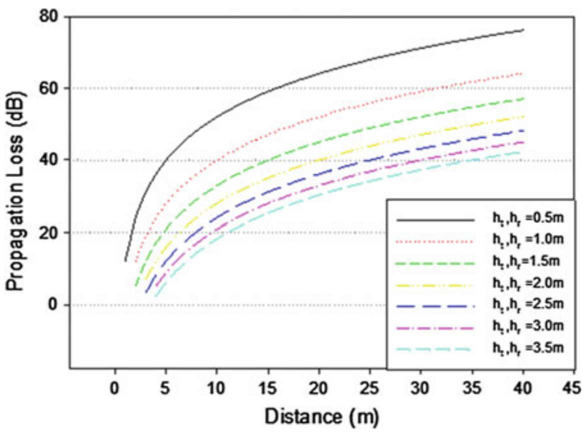

Fig. 1 Path loss versus separation distance for equal antennas height of 0.5, 1, 1.5 and 2 m

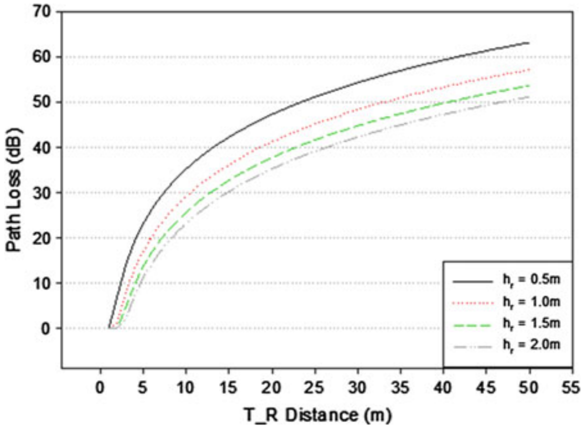

Fig. 2 Path loss versus antenna separation distance for h_t of 3.5 m and h_r of 0.5, 1, 1.5 and 2 m

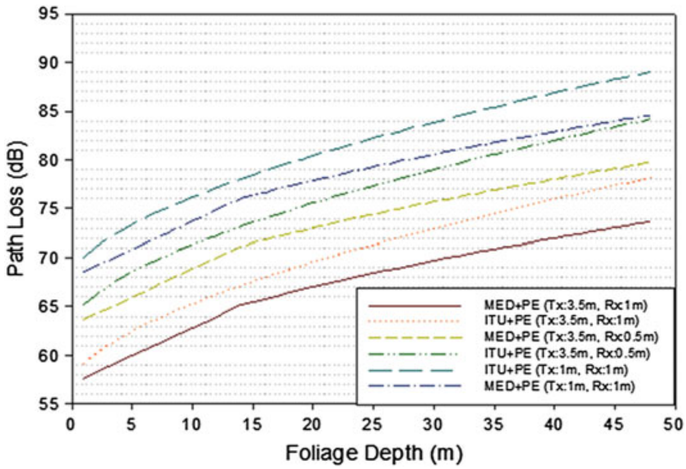

Fig. 3 Antenna height effects on total path loss for MED and ITU vegetation models and T-R model

of height for receiver antenna, these parameters will be applied to MED and ITU-R models.

As a conclusion of the effects of antenna height of the node transceiver on the total path loss are depicted in Fig. 3, the combination of height of 3.5 and 1 m shows less total path loss (73, 78.15 dB for MED and ITU models respectively for max foliage depth) as compared to height of 3.5 and 0.5 m where the total path loss is shown to be 79.78 and 84.18 dB for MED and ITU models respectively. This true since the first Fresnel zone must be clear out of obstacle and maximize the wave strength toward the receiver and the 0.5 m of receiver antenna height is less than the

Fresnel threshold of the first zone. Contrary for equal height of antennas of 1 m, the total path loss is shown to be higher, hence for MED model the loss is found to be 84 and 89 dB for ITU model. This also shows that the best antenna height based on greenhouse environment and total path loss is shown to be with the 3.5 m and 1 m height for transceiver of main and end node.

The main benefits from the simulation is that it easily shows the effects of network nodes height configuration on the reliability and performance of the network, hence it's a good indication of how far the total losses can affect the received signal strength in vegetation environment. This simulation can be used in prior of real time hardware deployment of the WSN nodes with proper calculation of maximum losses that can be damped our network signal propagation and hence degrade the total performance and reliability.

8.1 Communication Coverage Simulation

Usually, based on the maximum coverage range, the wireless sensor network nodes are deployed so that best connectivity is obtained. Hence for a larger communication range of a wireless node, the further it can be deployed. Although that the hardware wireless node has a maximum communication range of 100–120 m within free space line of sight situation, while in many cases of real experiment, communication failed either because proper studies were not been carried out to estimate the communication coverage of the node before deployment in the real environment or the maximum data sheet communication range is achievable only in ideal environment which is little bit different form real time application environment.

Figure 4 shows the communication coverage versus foliage depth for total path loss with various antenna heights. The simulation results shown in figure explain the effects of various vegetation depths between the main node and the end node, the sensing node. The investigation of the network communication coverage and hence the network performance is carried out based on the results shown. Using of only T-R model (PE) alone shows that the coverage distance is uniform at 187 m. Contrarily, the communication coverage decreases with increasing of vegetation depth for both MED and ITU models combined with the T-R model. For example at a height of 3.5, 1 m of antennas the MED+PE model expresses a decreasing of communication coverage from 180 to 134 m for vegetation depth of 1–10 m, respectively. The MED+PE for 3.5, 1 m of antenna height has more coverage range than 3.5, 0.5 m combination height of antennas, also MED+PE shows higher coverage than ITU+PE model and this due to the fact that the ITU model expresses higher loss than MED model (5) and (6).

At antenna height of 0.5 m for both models, the communication range is below 43 m for all vegetation depths. This is true since the height of the antenna has a significant effect on communication range. Overall, the communication range of a network shows a limitation of network nodes placement with respect to main node, the distribution of network nodes must be with consideration of the communication

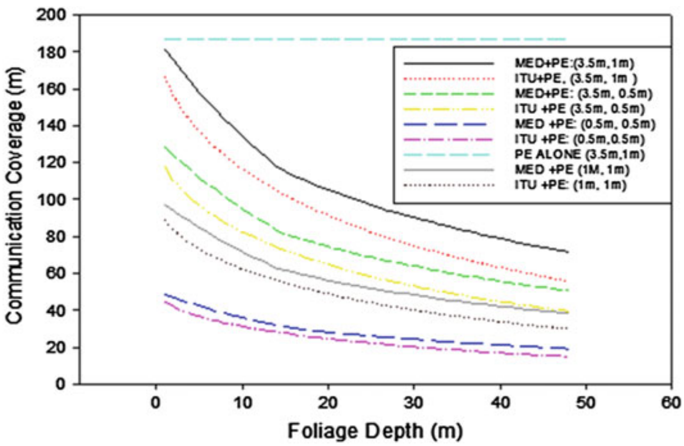

Fig. 4 Communication coverage for various foliage depth and vegetation models, MED and ITU

range of the nodes so that maximum coverage can be achieved and hence network nodes can communicate easily which gives better network performance than a situation where some nodes of the network is out of coverage.

The simulation used, Fig. 4, shows the communication range for the network based on 85 dB sensitivity of the receiver and various depths of vegetation loss, the simulated models shows worthy information on how far a node can be deployed far away from main node and how much vegetation depth can be in the way between them. Hence the real implementation of network nodes in the field has a prior awareness of the maximum dimension that must follow for nodes deployment while simulation results is little deviated from real time implementation due to other effects like grass, iron stand, roof, atmosphere that could contribute in more losses which is neglected during the simulation phase. The antenna heights play an important role in communication coverage and hence will extend the node deployment positions which give more flexibility for the network to cover a wide area with the same capability.

8.2 Network Connectivity Simulation

WSN based on a star topology requires that all wireless end nodes have the ability to direct communication with the main node, hence to achieve maximum connectivity of network nodes, a precise study of nodes positioning should be done prior to implementation. The connectivity simulation of network nodes will identify all the sensor nodes which are within the range of the main node. The connectivity percentage can be defined as:

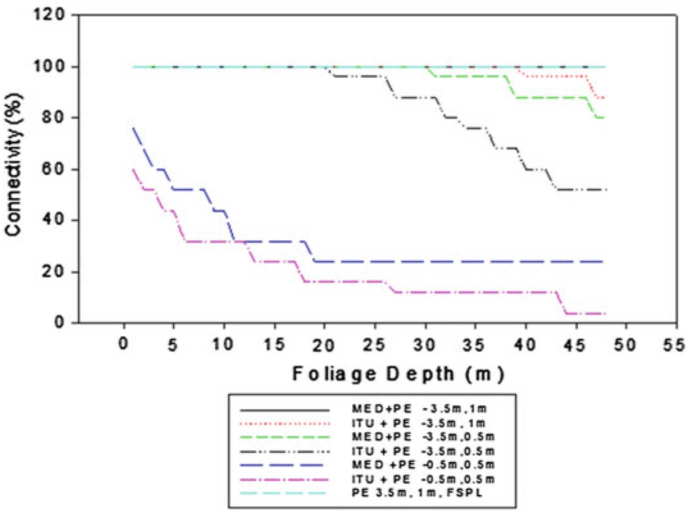

Fig. 5 Network connectivity for different antenna height with propagation models in vegetation

$$Connectivity = \frac{N_{con}}{N_{node}} \times 100\,\% \tag{10}$$

where N_{con} is the total number of connectivity and N_{node} is total number of nodes in the topology.

Figure 5 shows the simulation result of MED and ITU model with T-R (PE) model at three different antennas height combination and for various vegetation depths. The non vegetation loss of FSPL and PE model shows 100 % of connectivity, an idealistic model of FSPL and antenna height of the T-R model gives 100 % of connectivity.

As the vegetation depth increases, the two vegetation models show less connectivity. The experimental studies in Meng et al. [4] reported that the total path loss for near ground propagation is the accumulation of the foliage and the ground reflection effects. For antennas height of 0.5 m, the MED+PE model shows 76 % of connectivity degraded to 24 % as foliage depth increased from 1 to 20 m for the MED vegetation model while less connectivity of 60 % for the ITU model degraded to 16 % for same foliage depth as shown in Fig. 5.

The MED+PE model at 3.5, 1 m antenna height shows 100 % connectivity, while the ITU+E model shows, at foliage depth of 40 m, decreasing connectivity reached 88 % on the other hand a perfect connectivity is achieved when foliage depth is less than 40 m. Contrary when the antenna height combination for transmit and receive are 3.5 and 0.5 m height the MED+PE model shows connectivity of 100 % when foliage depth is less than 31 m while for more foliage depth greater than 30 m the model shows decrease in node connectivity reached to 80 %. The same behavior of the ITU+PE model is shown for 3.5 and 0.5 m antenna height combination, the model shows a perfect connectivity before 20 m of foliage depth while decreasing in connectivity shown, reached to 52 %, for higher depth of the foliage.

The ITU+PE model results in Fig. 5 shows lower connectivity as compare to MED+PE model for all antenna height. It's clear shown that when WSN nodes deployed near the ground and its antenna height is low causes higher difficulties in connectivity and hence need either more node power, rearrangement of node positioning or higher nodes' antenna. Contrary when antenna height increases, the percentage of connectivity will be improved.

Based on (3), the analytical calculation proves that greater than 0.9 m of antenna height is required to clear ground reflection. Therefore, based on these results, the antenna height of each end node should be positioned higher above the ground so that optimum connectivity between the nodes is assured. And as shown that the combination of 3.5 and 1 m heights of antennas shows perfect connectivity when used with MED vegetation model for all vegetation depth and ITU model shows perfect connectivity for same height combination but with less foliage depth of 40 m than MED model.

9 Conclusions

The electromagnetic wave propagation in close proximity of the earth's surface can be predicted using propagation models that show the attenuation of traveling signals. Although there are propagation models which are normally used in the conception and analysis of wireless communications networks, these models cannot be directly used in applications that use wireless sensor networks, based on WPAN (Wireless Personal Area Network) technologies, such as IEEE802.15.4. In this chapter, two foliage model, MED and ITU-R, have been simulated, and the height of the antenna for different procedure also have been determined as an effect of loss, basically line of sight communication cannot be achieved in the real environment of agricultural application due to reflection, diffraction and scattering effects.

Inside greenhouses, the distances separate wireless nodes almost are within the range of reliable communication link even the foliage is highly dense. The maximum foliage dense simulated is less by one meter than maximum distance between transmitter and receiver nodes.

In this study, the effect of vegetation on WSN systems' performance is investigated and discussed. The results shown that FSPL and PE models show over optimistic output although that there is vegetation in the transmission path. There is different Radio wave propagation models with different results used to model the radio communication channel. The results show that even for short range, the path loss can be considerable as the radio wave is impairment by vegetation and reflection. Therefore it is crucial to pick the appropriate propagation model based on the environmental effects, since the evaluation of new protocols using inappropriate propagation model may yields of wrong results and conclusions. The communication coverage and network node connectivity are simulated with 100 nodes spatially equal distributed in 100 m × 100 m area, the nodes were 10 m apart. The combination of MED+PE propagation model with 3.5 and 1 m antenna height of transmission and receiving nodes respectively shows perfect result with the simulation setup, the communication coverage for MED+PE shows the minimum coverage range of 80 m when foliage depth is 48 m and perfect connectivity. Contrarily ITU+PE model is less than MED+PE model while it still in acceptable results with simulation setup for same heights of antenna.

Results obtained in this study shows that the antenna height of the transceiver for network nodes is one of the most important issues when deploying of WSN system. Hence antenna positioned at ground or near the ground causes short range for WSN and the system will fail when implemented in the real environment. So that to maintain high network node connectivity, a proper node placement strategy must follow that assure of proper height of the antenna with respect to application allowance. Therefore, adequate propagation model should be used to predict antenna heights and path loss to ensure that the system maintains link connectivity.

Finally, the simulations prove its usefulness to use and combine with WSN simulators, hence its assist in the investigation of path loss, antennas height affect, network coverage and network nodes connectivity based on well known foliage vegetation models. The simulators are developed with the use of MATLAB m-files which is based on C like structure programming which make it easy to be combined with simulators like OMNET++, NS2 and OPNET that is based on C structure programming.

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