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Wireless Signal Propagation Analysis on Connected Autonomous Vehicle Test Bed in Northern Malaysia

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Abstract – *Connected and Autonomous Vehicle (CAV) technologies are among the most heavily researched automotive technologies in the industry with regards to making it more efficient and flexible for the user. This paper discusses the signal profile observed on connected autonomous vehicle testbed environment in an approved UniMAP Circuit. Wireless devices were used to perform channel measurements in such an environment. Data were collected and observation was recorded and analysed. The purpose is to analyse and evaluate signal propagation properties for the optimization of wireless roadside devices in CAV application such as junction controller. Two important paths have been chosen to represent the environment and transmitter to receiver communications were measured and characteristics are recorded at which Path 1 is on a tar road while Path 2 is a mix of gravel-tar-grass field. The result shows that both paths show an abrupt decrease in signal power for the first 10 m showing the diffusion region of signal propagation and then starts to fluctuate between -62 dBm and -93 dBm for Path 1 while it fluctuates between -44 dBm and -79 dBm for Path 2. From these results, we can conclude that the performance of the signal profile differs relative to the different surfaces they propagate. These results will definitely have a major effect in the application of any Vehicle-to-Infrastructure (V2I) technologies in regards to signal propagation being analysed beforehand, making sure that the signal transmission works at its best.*

Keywords: Junction controller, signal propagation, Vehicle-to-Infrastructure (V2I), Connected and Autonomous Vehicle (CAV)

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1.0 INTRODUCTION

The usage of wireless devices for application in daily lives activities have been rapidly gaining attention especially in an automated and autonomous system as it eliminates the implementation of wired and corded devices in order to simplify and minimize the hardware needs in a system. This has been a variegated study as the signal propagation and profiling depends on the effect of scattering, diffraction, reflection and even absorption of signal (Ali et al., 2010). This leads to a more subjugated study on signal propagation and profiling in the signal of a device and its surroundings in order to allow a stable and more efficient signal transmission making the ability to predict the behavior of signals especially in an outdoor environment such as on the road. The propagation of the signal in a wireless system, in other words, has been a significant factor in determining the performance of the wireless device as it determines the signal profile and efficiency of it. Some researchers have proposed the measurement in the agriculture environment to understand the significance of various types of vegetation on signal propagation (Harun et al., 2013). There have also been works on signal propagation study in various environments (Harun et al., 2011); however, those involving signal profile analysis for Connected and Autonomous Vehicle (CAV) application has been very minimum.

The propagation mechanism of the signal transmitted refers to how the signal is being propagated. Scattering, reflection, and diffraction are the most common mechanism that encountered in typical signal transmission. Figure 1 shows the three types of propagation mechanisms that we may encounter during the signal propagation analysis (Ali et al., 2010).

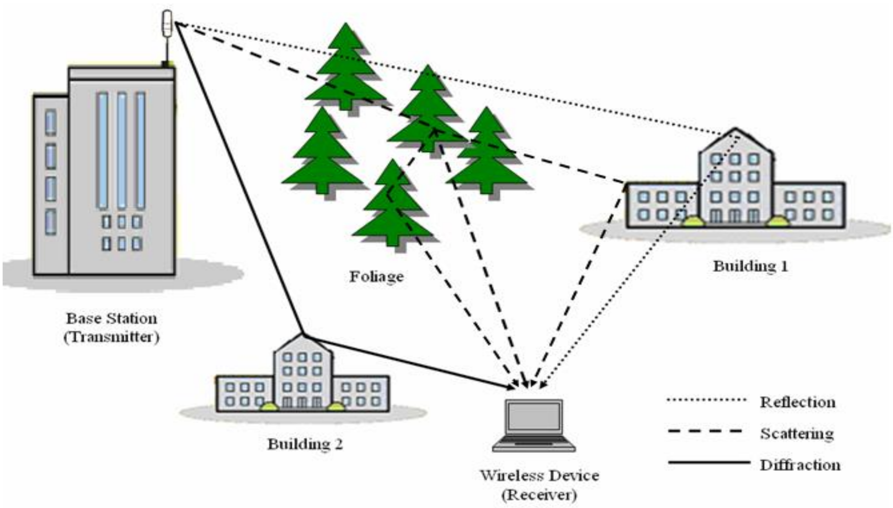

Figure 1: Types of propagation mechanism

Scattering occurs when the transmitted signal is faced with large numbers of small dimension objects like that of metal cabinets, lamp posts. The reflected energy during the scattering process is spread out in multiple directions before reaching the receiver (Ali et al., 2010). This shows that the signal power transmission does not efficiently happen even though the signal is received in the end.

For reflection, it happens whenever the transmitted signal encounters an object with large dimensions as compared to its wavelengths such as walls, ceilings, and sofas. Some of the signals that have been transmitted will be absorbed through these medium and the remaining will be reflected off of the medium's surface (Turner et al., 2014).

While diffraction occurs whenever there are obstacles or objects that have sharp edges resulting in a secondary signal that in effect bend around the obstruction (Ali et al., 2010). In normal situations, these aspects need to be taken into consideration whenever analyzation of signal propagation is performed. For the purpose of this experiment, we have determined that the best and suitable place to collect meaningful data is at Universiti Malaysia Perlis's (UniMAP) circuit located on the main campus. The reason for choosing UniMAP's circuit was due to the proximity of the location to our main campus making it easier to access. This has given us the ability to access and control variables that might be affecting the performance of the signal propagation measurement. The affected variables include temperature and humidity of the location during the measurements, objects or obstacles on the road that may be obstructing the Line of Sight (LOS) such as cars and barriers, and the placement of nodes for the transmission between transmitter and receiver. Figure 2 shows the layout of UniMAP's circuit, while Figure 3 shows the paths to be measured. The objects inside the circuit are kept fixed without any traffic and the number of people is kept as minimum as possible to ensure the effectiveness of the human body on signal propagation is suppressed. The selection of this location may lead to an improvement in the setup and could be a reference for the future development of any Vehicle-to-Infrastructure (V2I) technologies.

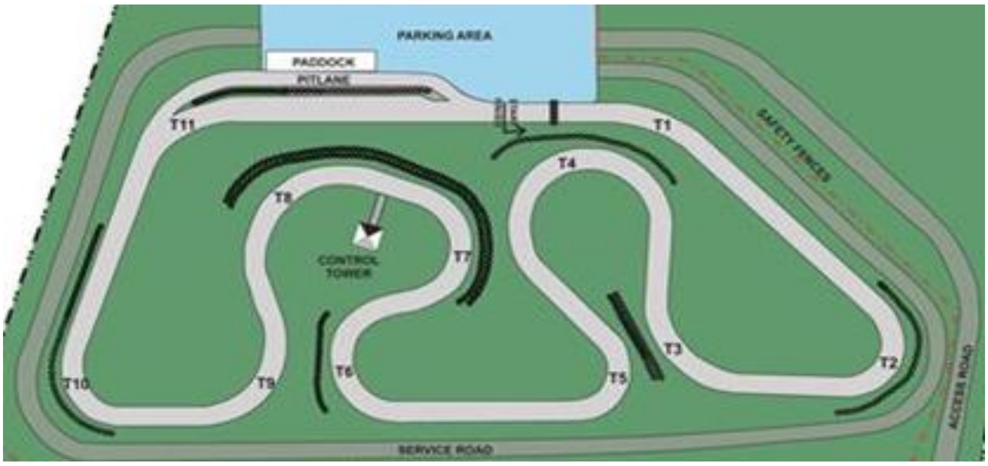

Figure 2: UniMAP's circuit layout

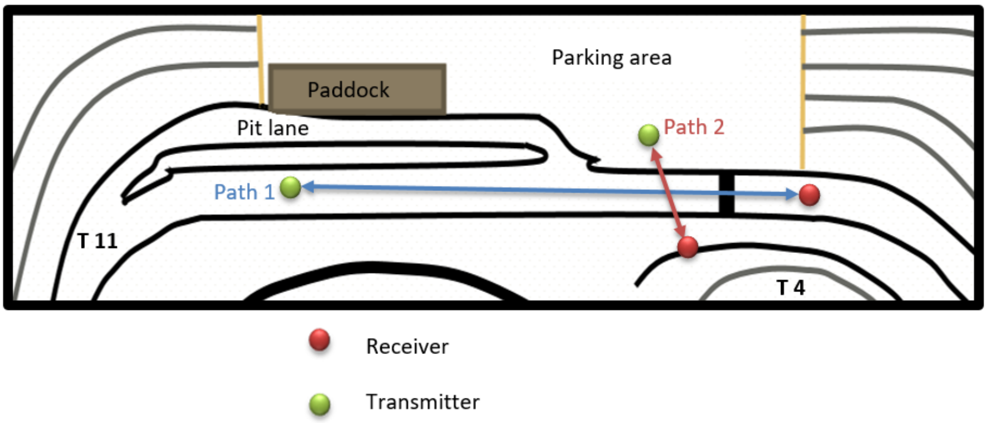

Figure 3: Path 1 and Path 2 allocation

2.0 EXPERIMENTAL SETUP

To start with, the area surrounding the UniMAP circuit was first explored and analysed in order to identify the best path to perform the study. Additionally, the conditions surrounding it were observed in case of any major effects that may influence the signal propagation study. Data collection setup was done by positioning two XBee S2C nodes on the paths elected; in which one node act as a transmitter and the other as received. These nodes operate in 2.4 GHz and antennas with a gain of 2 dB. The specification of the node is given in Table 1.

Table 1: XBee S2C specification

Specification	**XBee Series 2**
Performance	
Indoor/urban Range	up to 133 ft. (40 m)
Transmit Power Output	2mW (+3dBm)
RF data Rate	250,000 bps
Serial interface data rate	1200 - 230400 bps (non-standard baud rates also supported)
Receiver sensitivity	-95 dBm (1% packet error rate)
Power requirement	
Supply Voltage	2.8 – 3.4 V
Operating current	40mA (@ 3.3 V)
Power down current	< 1 uA @ 25oC ISM
General	
Operating Frequency Band	ISM 2.4 GHz
Dimensions	0.960” x 1.087” (2.438cm x 2.761cm)
Operating temperature	-40 to 85º C
Antenna options	Integrated whip, Chip, RPSMA, or U. FL Connector
Networking and security	
Supported network topologies	Point-to-Point, Point-to-Multipoint, Peer-to-Peer & Mesh
Number of channels	16 Direct sequence channels
Addressing options	Pan ID and Addresses, Cluster IDs and Endpoints

Both transmitter and receiver were placed at a fixed height of 80 cm that was about the waist height of adult men as shown in Figure 4. The height was not varied in order to analyze whether the environmental factors such as the surface types that will be tar, gravel, and grass will have any effects on the signal propagation whenever a signal is transmitted from the transmitter to the receiver. Other than that, the path for each signal profile to be studied will also be determined which will be shown in Figure 5.

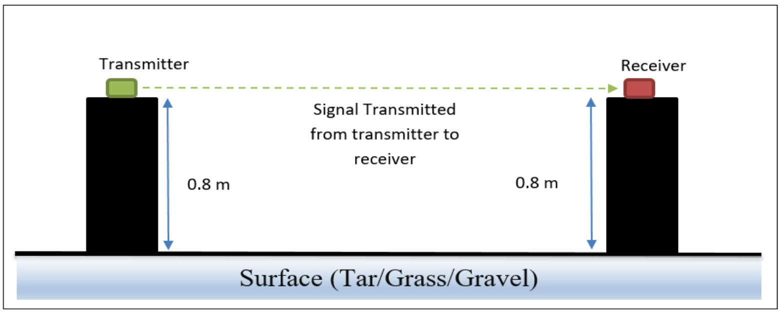

Figure 4: Nodes location and height

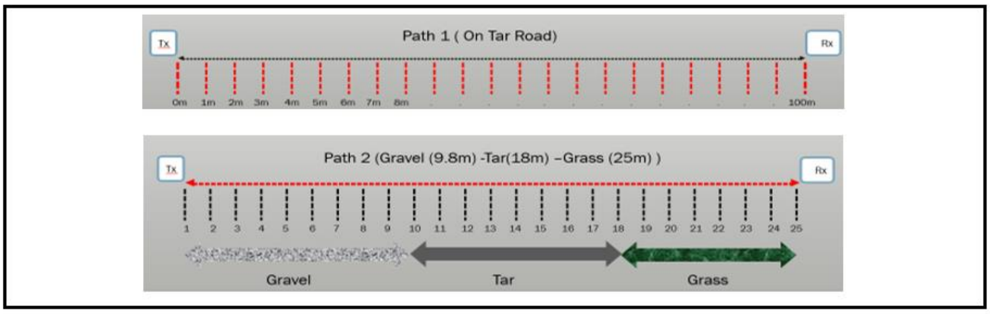

Figure 5: Path designated for signal profiling

For Path 1, the signal profile studied was a straight line cut along the circuit length which gives the longest possible tar surfaces in the circuit. A fixed transmitter with a height of 0.8 m was placed above the tar road while continuously transmitting data to a receiver that will be moving away from the transmitter in intervals up to 99 m away from the transmitter. Then for Path 2, the measurement was done across the surface of gravel-tar-grass as shown in Figure 5. The path was taken across the track starting from gravel area for a distance of 9.8 m, then tar road for 8.2 m and then grass for 7 m totalling for a path of 25 m. The build-up for transmitter and receiver will be the same as Path 1 analysis and also the same height. Compared to Path 1, Path 2 was designed to study the signal propagation while having to travel across 3 different ground surfaces from the transmitter to the receiver.

3.0 RESULTS AND DISCUSSION

The results from the experiment illustrated in Figure 6 and Figure 7 are observed and discussed.

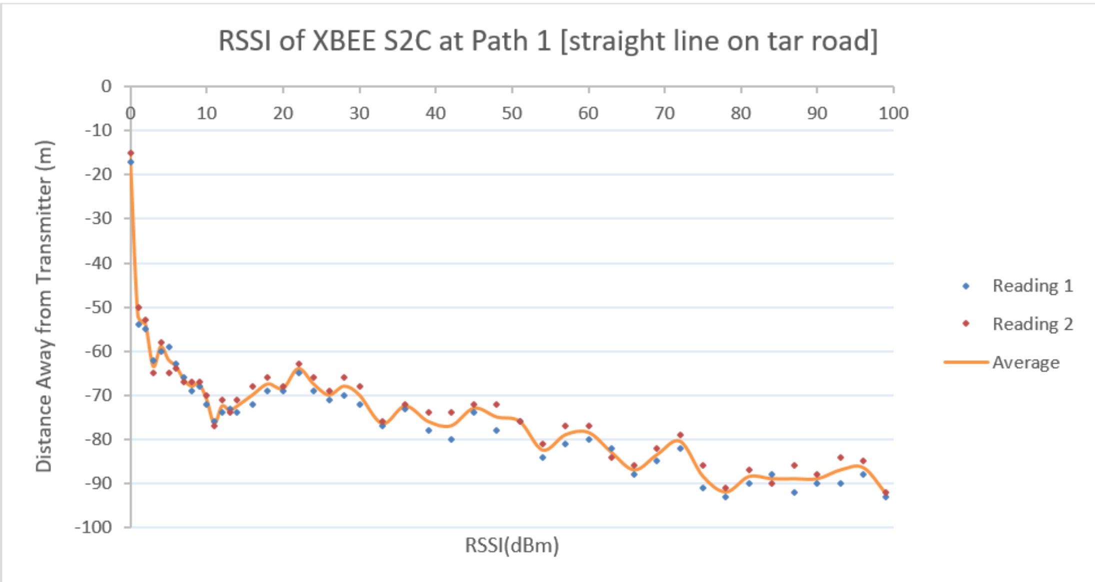

Figure 6: Graph of RSSI of XBee S2C at Path 1

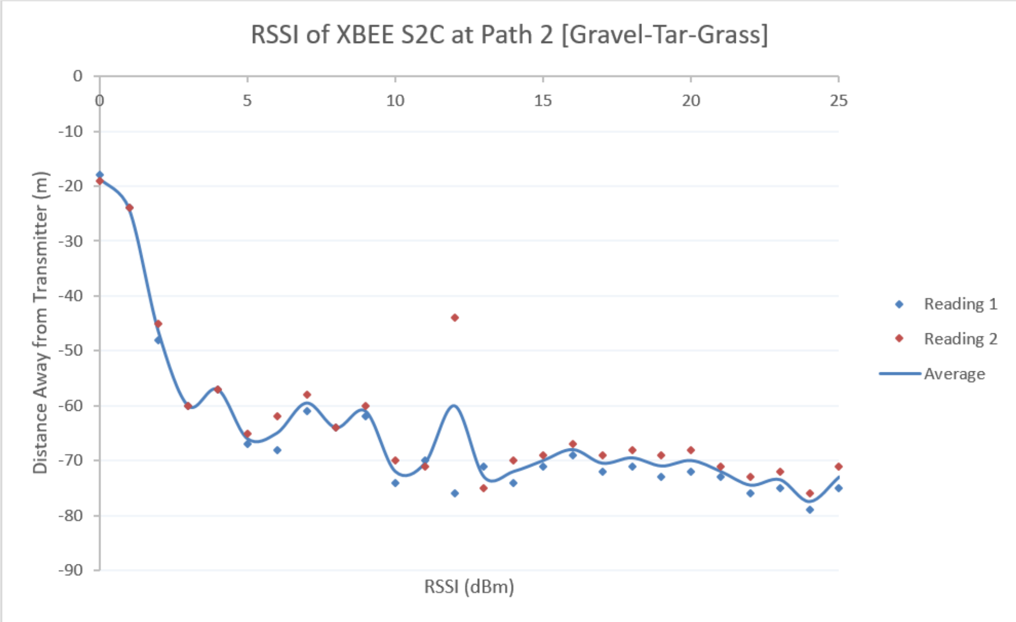

Figure 7: Graph of RSSI of XBee S2C at Path 7

Based on the graph shown in Figure 6, signal propagation obtained from the experiment done shows an abrupt reduction in signal power beginning from 0 m away from transmitter until the 10 m mark range. Signal power reaches -76 dBm at the lowest that indicates the start of the diffusion region of the signal transmission.

After the 10 m range, signal power bounced/increased to about -64 dBm at the highest value which corresponds to the 24 m range. This is mainly due to the ground reflection adding some power to the overall signal as the signals travel along the path from the transmitter towards the receiver. The effects of scattering from the ground are observed through fluctuations of signal power in this range.

As the range increased, the signal power decreases gradually as the scattering effect drags the signal power down until the end of the path. Signal power reached the maximum of the receiver's sensitivity after about 98 m range. The signal propagating from the transmitter to the receiver shows a fluctuation in which is due to multiple ground reflection provided by the tar surface of the circuit.

Figure 7 shows signal variation measured on three types of ground on path 2. The signal propagation profile obtained from the experiment shows an abrupt reduction in signal power beginning from 0 m away from transmitter until the 5 m range. Signal power reaches about -68 dBm at the lowest point indicating the start of the diffusion region of the signal transmission. From 5 m to 10 m range, there was some upward reflection of signal power potentially due to the effect of gravel ground causing a combination of multipath signals signal power as they traverse from the transmitter to receiver.

After the 10 m range, signal power increased to about -44 dBm at the highest which was at the 12 m range. This is mainly due to the ground reflection provided by the smoother tar ground. Signal power continues to gradually decrease as the scattering from tar ground reduces the power. This range, however, shows the highest fluctuation due to the roughness of tar ground surfaces. After 18 m range, the signal profile shows a decrease in power, however, the amount of fluctuation is very minimum. The grass surface attenuation contribution seems almost uniform across the range as provided by the scattering effect. As the signal profile reaches the end of the path, the signal power measured about -78 dB at the lowest point. The path ends before signal power reaches the receiver's sensitivity of the wireless node.

4.0 CONCLUSION

From the results obtained in the experiment, it could be concluded that the performance of the signal profile differs relative to the different surfaces they propagate. The signal profile for Path 1 shows a different characteristic compared to signal profile on Path 2 since this path is characterized by a single type of ground surface. Meanwhile, signal profile for Path 2 is characterized by three types of ground surfaces. Signal power traverse on Path 1 shows a uniform gradual decrease and seems to be more predictable while signal power traversing on Path 2 shows different contributions to the power reduction versus range. This leads to a more subjugated and variegated study in order to perform and predict the optimal signal propagation in the transmission of a signal in the signal transmission process in the future. A comprehensive study on the profile of wireless signal operating around the specified testbed would be imperative in order to gain the contribution of each obstruction towards signal propagation so the effect could be simulated to be helpful in quantifying the capability of junction controller to manage traffic in the area in CAV environment.

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