Temporal Measurement of UHF Radio Wave in Presence of Vehicles

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Abstract — Use of wireless sensor network for traffic and parking lot monitoring is very attractive. However, the network performance is difficult to predict due to complex radio wave propagation characteristic. In this paper, receiving signal level is measured for UHF radio wave in presence of vehicles. We perform measurement in two scenarios: 1) a parking lot and 2) a small street. We have found that the probability density function (pdf) of receiving signal level in small street scenario exhibits two peaks while only one peak is observed in the parking lot environment. The complement cumulative distribution function (CCDF) of receiving signal in both full and empty parking lots are similar. However, the average signals level in the full parking lot of lower than the empty parking lot. Level crossing rate (LCR) is also calculated for each scenario.

Key words: wave propagation, wireless sensor networks, diversity.

I. INTRODUCTION

There are many attempts, which require real-time traffic information, to solve traffic problem. A wireless sensor network is an attractive choice to gather traffic information since it is convenient to install and maintain. One major problem in large city is traffic jam due to inappropriate traffic signal control. The wireless sensor network can provide real-time traffic information so that traffic lights in the area can be properly controlled according to traffic condition. Another major problem in urban area is available spaces in a parking lot. The wireless sensor network can provide some crucial information how many and where spaces in the parking lot are available before the vehicles enter the parking lot.

The wireless sensor network consists of server nodes and sensor nodes. Typically, sensor nodes are installed on the road surface and they transmit data to the server nodes via wireless channel. Communication between the sensor nodes and server nodes utilizes radio wave propagated through moving vehicles. The moving vehicles reflect and obstruct the radio wave and, hence, such environment creates a number of multipath components. Moreover, multipath components are time varying due to moving vehicles. This severe multipath environment strongly degrades receiver performance. In order to improve receiver performance, statistical information of multipath components is required.

Statistical properties of multipath components heavily depend on scatterers characteristic. Due to small scale of the propagation and moving scatterers, the propagation characteristic is difficult to model. Hence, to understand the propagation behavior, the channel measurement is required. In this study, we perform amplitude characteristic of propagation channel using a channel sounder. The channel sounder consists of standard RF measurement equipments. The channel sounder is used to measure receiving signal level in two different scenarios. The first scenario is a parking lot environment which consists mostly of non-moving vehicles and, hence, the multipath components do not vary much with time. The second scenario arises in traffic monitoring application in which the wireless sensors are installed in heavy traffic scenario. Moving vehicles in this scenario create time varying multipath components.

The paper is organized as follow. In the first section, the measurement system is discussed. Section II-B shows measurement results on the parking lot. The measurement results on the small street are in section II-C. Section III concludes the paper and discusses possible future works.

II. MEASUREMENT CAMPAIGNS AND RESULTS

A. Measurement scenarios and channel sounder system

The channel sounder consists of a transmitter, receiver and signal processing unit. The probing signal is BPSK modulation with bit rate of 50 kbps which is modulated to 2.45 GHz by Agilent signal generator model E4433B. The signal bandwidth for BPSK with $\alpha = 0.5$ raise cosine filter is about 75 KHz. The signal is transmitted using a dipole antenna with 4 dB gain. The signal power is set to be constant at 10 dBm.

The receiver consists of Agilent N9020A MXA signal analyzer connected to the receiving antenna via a low noise amplifier with 28 dB gain. The receiving complex signal is demodulated by Agilent 89600 vector signal analyzer software installed in the Agilent N9020A. The software acquired the receiving signal in the form of

\begin{equation}
    y(t) = i(t) + q(t)
\end{equation}

The receiving signal is acquired for two seconds and sampled at 320 ksps. Hence, the number of sample is 640,000 samples.
per measurement. The sampled receiving signal is stored to the hard disk of the Agilent N9020A. The signal is then processed off-line using MATLAB software. The signal amplitude and phase are simply calculated by

\[ r(t) = \sqrt{i(t)^2 + q(t)^2} \]  
\[ \phi = \tan^{-1} \frac{q(t)}{i(t)} \]  

Fig. 1 The transmitter and receiver for the measurement

B. Parking lot

To investigate receiving signal power in the parking lot, the measurements are performed in two extreme cases. The first scenario is an empty parking lot representing radio propagation without any random obstacle. Another extreme is a full parking lot where all vehicles act as scatterers. By performing measurement of signal level on these two scenarios, the total signal fluctuation should be captured.

The parking lot is outdoor type with metal roof. The height of roof is about three meters as shown in Fig 2. The measurements are performed on two different conditions on the parking lot. The transmitter and receiver are 6 meters apart. Both transmitting and receiving antenna height from the ground is 2 meters.

Fig. 2 Parking lot scenario

We first study statistical behavior of the receiving signal amplitude in both scenarios. In order to understand this statistical behavior, we examine the signal amplitude pdf. The pdf represents the “density” of probability at the receiving signal amplitude. Hence, it can be utilized to determine the receiving signal fluctuation. The receiving amplitude distribution of the empty and full parking lot is shown in fig. 3. The measurements show that the amplitude distributions in the empty and full parking lots are similar. The only difference is the average receiving signal amplitude. The vehicles in the parking lot influence only on the average signal attenuation. Variation of the signal level depends on the structure of the parking lot because the pdf of both cases are similar.

We further investigate probability of the receiving signal level. In order to illustrate the receiving signal probability, the empirical complement cumulative distribution (CCDF) [1, 3] is calculated for both cases. CCDF associates the receiving signal level being greater than a particular value with a probability. Fig. 4 shows the CCDF of signal level in both empty and full parking lot. Let us consider the CCDF of full parking lot signal level of -60 dBm. It will be 6.51% of the receiving signal being less than -60 dBm. There is another benefit of using CCDF to indicate the channel characteristic. Different channels can be compared by the signal level different at the same probability. For example, let us consider the probability at 90%. The signal levels in full and empty parking lots are -58.45 dBm and -50.26 dBm respectively. The signal difference is 8.19 dBm. This signal level difference can be use in performance evaluation of various propagation scenarios.

Fig. 3 Pdf of the receiving signal level in the empty parking and the full parking

Fig. 4 CCDF of receiving signal level in the parking lots
Dynamic of receiving signal level can be visualized by fading envelop. The fading envelop plot is normalized to root mean square (rms) power. The fading envelop of full parking lot case is shown in Fig. 5. It can be observed that there is only small fluctuation in the fading envelop since most of scatters are stationary. Next, we calculate the level crossing rate (LCR) [1] of the receiving signal. Fig. 6 shows the LCR for both full and empty parking lot. It can be seen that the highest LCR is about the rms signal level in both cases. However, in full park lot, the LCR are spread into the lower threshold area due to higher signal loss.

Sedan cars and motorcycles are observed in the experiment. The first traffic condition is a sedan car and two motorcycles are moving in opposite direction. It can be seen from the pdf shown in fig. 8 that there are two signal concentrations at low and high power region. The signal in low power region corresponds to the signal blocking due to the moving car. The peak in high power region represents the signal propagation without any obstacle.

When a motorcycle and a motorcycle are in the opposite direction, the amplitude fluctuates in high power region as shown in fig. 8. The receiving signal in motorcycle case is higher than the signal in previous case because the motorcycle is smaller than car. Thus, the duration of signal blocking is shorter and the signal attenuation is lower.

C. Small Road with traffic

The measurements are performed on a road side with various traffic conditions. The distance between the transmitter and receiver is five meters. The corresponding minimum propagation delay is 16.7 ns. We approximate the exceed delay is ten times of the minimum delay and, hence, coherence bandwidth is 6 MHz. The probing signal is 75 kHz which is much smaller than the coherence bandwidth. Thus, the channel is flat fading. The antenna position is 0.5 meters above the ground as shown in Fig. 7. The average vehicle velocity is about 40-60 km/hr.
Fig. 8 Pdf of the receiving signal level in a car and two motorcycles and a motorcycle and a motorcycle are moving in opposite direction

Fig. 9 CCDF of receiving signal level in the road

Fig. 10 Fading envelop when a car and two motorcycles are moving in opposite direction

Fig. 11 Level crossing rate (LCR) for car-motorcycle and motorcycle-motorcycle scenarios.

III. CONCLUSION AND FUTURE WORKS

In this paper, dynamic of signal level in radio propagation channel in presence of vehicles is studied. We perform receiving signal level measurements in two difference scenarios. The results in the street scenario show that the signal level is more fluctuated than the parking lot case. There is evidence that the moving sedan car significantly reduce the receiving signal level. In the parking lot scenario, signal level variation is small.

The measurement results can be utilized to design diversity system for the wireless sensor network. With temporal channel information, time diversity techniques can be employed. For example, diversity system for small road scenario has to be capable to receive signal with a curtain period of outage.

To fully utilize diversity scheme, spatial channel information is required. We plan to study spatial channel characteristic in the future with our existing channel sounder.

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