Abstract—The received signal strength indicator (RSSI) is a measurement of how well devices can receive the transmit signal, which varies due to various in-path interference. In this paper, we aim to analyze the pattern of RSSI in both space and time in a wireless sensor network setup. Specifically, we first collect data generated by one transmitter and two receivers placed in different floors of an apartment for one week. Then, we examine the pattern in space and time using the autocorrelation and cross-correlation functions. The results of the statistical analysis shed light on how the receive signal varies over time and space, which helps us predict future RSSIs in an energy-efficient sensor network under given conditions.

Keywords—Autocorrelation, cross-correlation, received signal strength indicator (RSSI), wireless sensor network

I. Introduction

Recently, there is an increasing demand for energy-efficient wireless sensor networks (WSN) [1], [2]. For example, a WSN is deployed by a gas service provider that collects the gas usage from all residents living in the same apartment at different times in a day in order to provide a customized plan for each household [3]. For energy efficiency, sensor nodes are mostly in sleep state and they only wake up for a short duration for data transmission. There will be a data loss if there is no transmission during this active time due to various disturbances at the receiver. Thus, it is of importance to schedule the active time of the sensors to balance the trade-off between energy consumption and data loss.

The received signal strength indicator (RSSI) [4] is an indication of the power level being received by the receivers (e.g., devices). Therefore, the higher the RSSI is, the stronger the received signal is. However, while there are some studies on how to use RSSIs for energy-efficient information dissemination in WSNs [5], the solution to an optimal scheduling of the active time for sensor nodes have not yet been investigated.

In this paper, we simulate one situation by deploying one transmitter and two receivers placed at three different floors of a building and then provide analysis of the collected RSSI. In more detail, we adopt the autocorrelation and cross-correlation functions to examine the pattern of RSSI in both space and time domains. The experimental results provide useful insight how the received signal varies over two-dimensional domains.

II. Methodology

A. Experimental Environment

We installed one transmitter and two receivers as depicted in Fig. 1. We expect that two receivers can only receive a diffracted wave reflected from other buildings via windows. In our experiment, the 920MHz frequency band is used. The RSSI was recorded for every five seconds at each receiver. Our dataset then consists of the time and the corresponding RSSI for seven consecutive days. Importantly, this recorded data include the influence of people and things moving within the building. To highlight the overall trend of the RSSI, we apply a moving average filter with the duration of one minute to the original data.

B. Proposed Model

First, we aim to provide correlation functions of the RSSI over time. More specifically, we separately examine the autocorrelation of RSSI on the second and third floors. We first denote the RSSI recorded collected from the second and third floors for every five seconds as \( X_i \) and \( Y_i \) for \( i \in \{1, ..., N\} \), respectively, where \( N \) is the number of records. Then, the autocorrelation function \( ACF(k) \) at lag \( k \) on the second floor is expressed as

\[
ACF(k) = \frac{\sum_{i=1}^{N-k}X_i(\bar{X})X_{i+k-\bar{X}}}{\sum_{i=1}^{N}(X_i-\bar{X})^2}, \tag{1}
\]

where \( \bar{X} \) is the expectation of \( X_i \) over \( i \). Similarly, we can compute the autocorrelation function on the third floor.

As the next step, we examine the cross-correlation of RSSI on both the second and the third floors. The cross-correlation \( CCF(k) \) at lag \( k \) is expressed as
In this paper, we divide the data into two separated sets according to day-time and night-time, where day-time dataset contains records collected from 8am to 8pm and night-time dataset includes those from 8pm to 8am of the next day.

Using (1), we continue on by plotting the autocorrelation function versus lag (in minutes) with the maximum lag of twelve hours (720 minutes) for the above day-time and night-time periods. For ease of presentation, we only present the results on second floor on Monday, Wednesday, and Thursday, which are illustrated in Fig. 2. From this figure, we observe that the autocorrelation is not stable during the day-time, while it tends to be more stable during the night-time. This is because during the day-time, other environmental factors such as human activity can unexpectedly affect the signal strength, while during the night-time, the absence of such factors leads to a more stable RSSI. It is worth noting that the value of autocorrelation is high in both day-time and night-time datasets for about thirty minutes, which would be promising for RSSI prediction.

Next, in Fig. 3, we provide the plot of the cross-correlation function versus lag (in minutes) with the maximum lag of twelve hours (720 minutes) for the day-time period on the second and third floors on Saturday using (2). Since the value of cross-correlation is low, it is difficult to see the correlation in terms of space between two series of RSSI in these two floors.

IV. Conclusion

In this paper, we presented the analysis of RSSI pattern in space and time. By modeling the autocorrelation and cross-correlation in RSSI series as a function of time and space, we observed high values of autocorrelation during day-time and night-time periods for about thirty minutes. Further developments such as the Markov model or recurrent neural network can be taken into account to predict future RSSIs at a node in WSNs given temporal information.

Acknowledgment

This research was supported by the MSIT (Ministry of Science and ICT), Korea under the National Program for Excellence in SW supervised by the IITP (Institute for Information & communications Technology Promotion) (no. 2017-0-00091).

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