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The Effect of Some Meteorological Parameters on Wireless Data Transmission

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ABSTRACT
It is essential to bring together the data measured in agricultural lands, greenhouses and animal shelters transmit to follow the data online. Wireless and wired systems have advantages and disadvantages. In wired systems, there is a cost of cabling, but data can be transmitted more securely. In wireless systems, system installation is cheap, but there are losses in data transmission. Wireless data transmission carried out in the outdoor environment takes place under surrounding climatic conditions. In this study, the effect of atmospheric meteorological factors on data loss in wireless data transmission system was tried to be determined. For this purpose, the losses that occur during the transfer of the data measured in the greenhouse in Bursa Uludağ University Faculty of Agriculture Research Farm to the office 150 m away are discussed. Temperature, humidity, precipitation, wind speed and atmospheric pressure were used as meteorological parameters, and 4 different frequencies from the civil use frequency range (2420, 2440, 2460 and 2480 Mhz) were used as data transmission frequency. The SPSS package was used for the correlation analysis with the data set. According to the results of the correlation analysis, relative humidity has a statistically significant effect on the data transmission losses at all data transmission frequencies ($p<0.01$). The temperature on the data transmission losses at 2420 and 2480 Mhz frequencies and atmospheric pressure at 2440 and 2480 Mhz frequencies have a statistically significant effect ($p<0.01$). The effect of wind speed on data transmission losses is statistically significant at data transmission frequencies other than 2460 Mhz frequency ($p<0.01$). The precipitation amount has no statistically significant effect on the data transmission losses at all data transmission frequencies.

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Bazı Meteorolojik Parametrelerin Kablosuz Veri İletimi Üzerindeki Etkisi

ÖZET
Tarımsal arazilerde, seralarda ve hayvan barınaklarında ölçülen verilerin bir araya getirilmesi, verilerin online takip edilmesi için esastır. Kablosuz ve kablolu sistemlerin avantajları ve dezavantajları vardır. Kablolu sistemlerde kablolama maliyeti vardır ancak veriler daha güvenli bir şekilde iletilebilir. Kablosuz sistemlerde sistem kurulumu ucuzdur ancak veri iletiminde kayıplar vardır. Dış ortamda gerçekleştirilen kablosuz veri iletimi, çevre iklim koşullarında gerçekleşir. Bu çalışmada kablosuz veri iletim sisteminde atmosferik meteorolojik faktörlerin veri kaybına etkisi belirlenmeye çalışılmıştır. Bu amaçla Bursa Uludağ Üniversitesi Ziraat Fakültesi araştırma çiftliğinde serada ölçülen verilerin 150 m uzaklıktaki ofise aktarılması sırasında meydana gelen kayıplar tartışılmıştır. Meteorolojik parametreler olarak sıcaklık, nem, yağış, rüzgar hızı ve atmosferik basınç, veri iletim frekansı olarak ise sivil kullanım frekans aralığından (2420, 2440, 2460 ve 2480 Mhz) 4 farklı frekans kullanılmıştır. Veri seti ile korelasyon analizi için

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Sera

SPSS paketi kullanılmıştır. Korelasyon analizi sonuçlarına göre, bağıl nemin tüm veri aktarım frekanslarında veri aktarım kayıpları üzerinde istatistiksel olarak anlamlı bir etkisi vardır ($p<0.01$). Sıcaklık 2420 ve 2480 Mhz veri iletim frekansında, atmosfer basıncı ise 2440 ve 2480 Mhz veri iletim frekanslarında veri aktarım kayıpları üzerinde istatistiksel olarak anlamlı bir etkiye sahiptir ($p<0.01$). Rüzgar hızının veri iletim kayıplarına etkisi 2460 Mhz frekansı dışındaki veri iletim frekanslarında istatistiksel olarak anlamlıdır ($p<0.01$). Yağış miktarının tüm veri aktarım frekanslarında veri aktarım kayıpları üzerinde istatistiksel olarak anlamlı bir etkisi olmadığı sonucu elde edilmiştir.

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INTRODUCTION

Wireless sensor networks can be used indoors as well as outdoors conditions. There are various factors that affect the data transmission of sensor networks. While metal-dense environment in closed environments affects wireless transmission, climate parameters under open-air conditions can influence the quality of data transmission (Bannister et al., 2008). Wireless sensors can be placed in different locations on the open field, anywhere without restrictions. Due to the advantage of wireless transmission, it is possible to transmit data over long distances. However, the variation of atmospheric conditions from location to location may also have an effect on data transmission. Wireless data transmission in outdoor conditions may have an impact on the quality and quantity of data. Significant decreases in system performance may occur (Luomala and Hakala, 2015). It is important to investigate the factors affecting the radio connection quality in order to reduce the effect of atmospheric conditions on wireless transmission and to adapt to changing conditions (Luomala and Hakala, 2015). Climate parameters that can be effective in wireless transmission are parameters such as humidity, temperature, fog, rain and snow. Various researchers have investigated these effects on this subject (Nadeem et al., 2010).

One of the key questions is “How does atmospheric conditions affect the ability of wireless sensor network (WSN) nodes to communicate?”. Partial answers to this question can be found in the literature (Marfievici et al., 2013). In some studies, the applicability of knowledge-centered network architecture for wireless sensor devices, its advantages and current shortcomings have been examined by considering the studies in the literature (Eriş and Boluk, 2021).

As a result of researches, it is known that temperature changes affect the performance of wireless sensor networks deployed outside. However, there are limited studies that reveal the common effect of other climate parameters besides the temperature parameter (Boano et al., 2010).

In this study, it was tried to determine the effects of parameters such as temperature, humidity, precipitation, wind speed and atmospheric pressure on wireless data transmission in open air conditions at 2420, 2440, 2460 and 2480 Mhz frequencies.

MATERIAL and METHODS

This study tried to determine the effect of temperature, humidity, precipitation, wind speed and atmospheric pressure, seasons, months, days and nights, and days of the week (working days and weekend) parameters on data transmission loss at different frequencies. Sensors measuring at different locations within the Uludag University Faculty of Agriculture greenhouse send the data to a collection station located within the greenhouse. Wireless data transmission takes place entirely under atmospheric conditions and the influence of meteorological factors. The hypothesis that meteorological factors may affect the number of data transmitted in wireless data transmission was investigated in the study. If there were no environmental or systemic impact, the hourly data numbers sent from the greenhouse and received by the receiver in the office would be equal. The difference between the number of hourly data transmitted and the number of data acquired will be zero. Many researchers have concluded that atmospheric meteorological conditions have an effect on wireless data transmission (Çaylı and Mercanlı, 2017; Luomala and Hakala, 2015; Wennerström, 2013; Boano et al., 2010).

At the collection station, the Raspberry Pi computer with a time sensor was used. The Raspberry Pi is a "real computer" the size of a credit card. It is used by everyone because of its capacity to do most things a computer can do, its small size and affordable price. The data was saved onto the SD card and sent to the Raspberry Pi computer in the office located 150 m away with the communication module (nRF24L01). The communication module has a transceiver feature. It is a module with low power consumption that allows you to communicate wirelessly at 2.4GHz frequency. Operating Range (Km) is 1 km with antenna, 100 m without antenna. There was no structure between the greenhouse and the office, data transmission performed under completely open atmosphere conditions (Figure 1). The data received by the Raspberry Pi computer in the office were recorded on the SD card. The frequencies of 2420, 2440, 2460 and 2480 Mhz were used to determine whether different frequencies have an effect on the data transmission. The same data is transmitted at each of these frequencies (Figure 2). Meteorological data were measured at the Turkish State Meteorological Service station within the University and the Agricultural Monitoring and Information System station of the Ministry of Agriculture and Forestry in the University. Temperature, relative humidity, precipitation, wind speed, and atmospheric pressure values were used as meteorological data. Each meteorological data were divided into class ranges for evaluation easiness (Table 1).

Data measurement and transmission from sensors took place every 5 minutes. To reduce the number of data to be evaluated, the number of data collected hourly was determined. The transmission data obtained from 10 different sensors in the greenhouse was transmitted via a wireless connection. Thus, the data used in the study could be matched with hourly meteorological data. Date and time information obtained from the time sensor used in the system was used in the pairing. The differences between the number of data recorded every hour in the greenhouse and the number of data recorded simultaneously in the office were calculated separately for each transmission frequency. Thus, losses in data transmission were determined on an hourly basis. The study was carried out to cover 12 months in 2016-2017. The SPSS package was used for the correlation analysis with the data set.

Figure 1. The Greenhouse and Office Locations Where the Study was Carried out at Bursa Uludağ University, Faculty of Agriculture

Şekil 1. Bursa Uludağ Üniversitesi, Ziraat Fakültesinde Çalışmanın Yürütüldüğü Sera ve Ofis Konumları

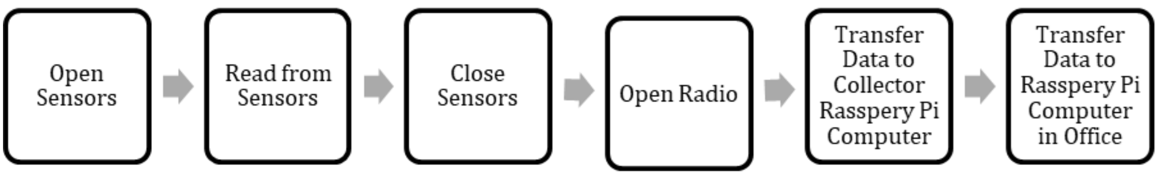

Figure 2. Flowchart for data collect and transfer of data

Şekil 2. Veri toplama ve veri aktarımı için akış şeması

Table 1. Class ranges used for meteorological parameters
Çizelge 1. Meteorolojik parametrelerin sınıflandırması

Classes	Temperature, °C	Atmospheric Pressure, mbar	Wind Velocity, m sn^{-1}	Precipitation, mm	Relative humidity, %	Season
1	<16	<1012	<3	<1	<60	9.,10. and 11.month
2	16 - 19	1012 – 1013	3 - 6	1 - 3	60 - 70	12.,1. and 2. month
3	19 - 22	1013 – 1014	6 – 9	3 - 4	70 - 80	3.,4. and 5. month
4	22 - 25	>1014	>9	>4	>80	6.,7. and 8. month
5	>25					

RESULTS and DISCUSSION

It was observed that the data set were not homogeneous and incompatible with the normal distribution. Therefore, the spearman distribution option of the SPSS package was used for the correlation analysis with the data set. According to the results of the correlation analysis, relative humidity has a statistically significant effect on the data transmission losses at all data transmission frequencies ($p<0.01$). The temperature on the data transmission losses at 2420 and 2480 Mhz frequencies and atmospheric pressure at 2440 and 2480 Mhz frequencies have a statistically significant effect ($p<0.01$). The wind speed has statistically effect on the data transmission losses except at 2460 Mhz frequencies ($p<0.01$). The precipitation amount has no statistically significant effect on the data transmission losses at all data transmission frequencies.

When data transmission losses are analyzed monthly, data transmission losses differ according to months ($p<0.01$). This shows that the differences in meteorological conditions between months are effective in data loss in wireless data transmission. When the losses in data transmission are analyzed on a seasonal basis, it is concluded that the differences in meteorological conditions between seasons have a significant effect on wireless data transmission at all data operating frequencies except the 2460 Mhz frequency ($p<0.01$). When wireless data loss was compared during the daytime (07:00-18:00) and nighttime (18:00-07:00), significant differences were obtained in all data transmission frequencies ($p<0.01$). There is statistically significant difference between wireless data transmission losses on working days and holidays except for the 2480 MHz wireless data transmission frequency ($p<0.05$). With the increase in human traffic in the area where this study is carried out, the wireless data signals of mobile phones, radios and vehicles may increase on working days. Increased wireless traffic may have an impact on wireless data transmission loss. However, no wireless data traffic measurement has been made to test this (Table 2).

Table 2. Correlation Coefficients for Data Transmission Loss between Different Frequency and Other Parameters
Çizelge 2. Farklı Veri İletim Frekansları ile Diğer Parametreler Arasındaki Korelasyon Katsayıları

	Data transmission loss for 2420 Mhz	Data transmission loss for 2440 Mhz	Data transmission loss for 2460 Mhz	Data transmission loss for 2480 Mhz
Months	-.184**	-.284**	-.078**	-.123**
Seasons	.148**	.207**	.006	.149**
Working days and weekend	-.025*	.025*	-.025*	-.002
Day and night	.070**	.084**	.071**	.047**
Temperature	.042**	.005	.001	.082**
Relative Humidity	-.085**	-.105**	-.090**	-.097**
Wind Velocity	.088**	.148**	.023	.085**
Precipitation	-.001	-.021	-.001	-.017
Atmospheric Pressure	-.010	-.045**	.019	-.051**
Temperature Classes	.016	.001	-.008	.056**
Relative Humidity Classes	-.092**	-.109**	-.087**	-.073**
Precipitation Classes	.016	-.005	.019	.001
Wind Velocity Classes	.067**	.148**	-.004	.063**
Atm.Pressure Classes	.011	-.027*	.024*	-.056**

Çaylı and Mercanlı (2017) determined the effect of greenhouse indoor environmental conditions on wireless data transmission performance. Their results showed that high relative humidity had a positive effect on the signal strength, while high temperature had a negative effect on the signal strength. In a study conducted in Sonoran Desert of the southwestern United States, the effect of temperature changes between 25-65 ° C on the Received Signal Strength (RSS) in wireless data transmission was investigated. It has been determined that there is a decrease in RSS with the increase in temperature (Bannister et al., 2008). In another study conducted to determine the effect of both ambient temperature and relative humidity values on the received signal strength, it was concluded that there was an inverse relationship between the temperature and the received signal strength. There was a correct relationship between the relative humidity and the received signal strength. When linear regression analysis was performed with the data power transmitted together with temperature and relative humidity values, it was concluded that the relationship is linear in the months when the temperature is high. There was no linear relationship in the months when the temperature is low (Luomala and Hakala, 2015). In another study, it has been tried to determine the effect of climatic factors on Packet Reception Ratio (PRR) in WSN. As a result of the correlation analysis, an inverse correlation was found between temperature, absolute humidity, sun time, and PRR, the correct correlation between relative humidity, rainfall, and PRR (Wennerström, 2013).

The temperature has been the main focus in past research, but there are discrepancies in the findings. According to the Holland et al. (2006), temperature has no impact on received signal strength indicator. Their view is also shared by Anastasi et al. (2004) do not observe a change in packet receptions over different distances during varying environmental conditions. In contrast, other studies Bannister et al. (2008) and Boano et al. (2010) show how higher temperature can reduce the received signal strength on a sensor node.

There is no statistically significant relationship between rainfall and data loss in the data transmission in our study. The results obtained from other researchers' studies show (Anastasi et al., 2004) that rain and fog cause a decrease in packet reception ratios. Another research (Boano et al., 2010) shows that rainfall, fog, and snowfall had no severe impact on the received signal strength during non-extreme conditions.

Our study concluded that the effect of daytime and nighttime on data loss in data transmission is statistically significant ($p<0.01$ level). At the same time, it was concluded that the time of day is statistically significant on data losses ($p<0.01$ level). In another study (Sun and Cardell-Oliver, 2006) show how PRR fluctuates during daytime and nighttime. Other researchers have also noted that there can be a large variation in the received signal strength and radio link performance during daytime and nighttime (Thelen, 2004).

Wilcoxon Related Two-Sample Tests were conducted to determine whether the amount of data transmission loss in different wireless data transmission frequencies in the same atmospheric conditions is compatible with each other (Table 3). For this purpose, all frequencies were tested in pairs. It was concluded that the data loss amounts at all frequencies were statistically different from each other ($p<0.01$). When the hourly averages of the data losses in the different frequencies are sorted from lowest to highest, the lowest data loss was obtained at the frequency of 2460 Mhz. The highest data loss was received at the frequency of 2440. Data losses from small to large were 2460, 2420, 2480, and 2440 Mhz, respectively.

Table 3. Wilcoxon 2 related samples test results
Çizelge 3. Wilcoxon 2 ilişkili örnek test sonuçları

Test Statistics

	Loss2440 - Loss2420	Loss2460 - Loss2420	Loss2480 - Loss2420	Loss2460 - Loss2440	Loss2480 - Loss2440	Loss2480 - Loss2460
Z	-12.722^{b}	-3.079^{c}	-4.278^{b}	-20.637^{c}	-4.311^{c}	-10.835^{b}
Asymp. Sig. (2-tailed)	.000	.002	.000	.000	.000	.000

a. Wilcoxon Signed Ranks Test
b. Based on negative ranks.
c. Based on positive ranks.

When the data losses in the classes in Table 1 were evaluated based on the class average the difference between classes was found to be insignificant statistically. Although the difference between classes is insignificant, the amount of data loss within the class is given in Table 3 in order from smallest to largest. For example, at 2420 Mhz wireless data transmission frequency, the lowest data loss occurred in the 5th class range at temperature, the highest data loss occurred in the 3rd class range at temperature (Table 4).

The fact that a large number of sensor data has been examined in the study has shown statistically that there is an interaction between data transmission and meteorological parameters. However, the R^2 values of this relationship less than 0.5 may be evidence that the relationship is not very strong. The results of other researchers' findings that are completely opposite from each other may explain this issue. If the data stack is too large, the result will be statistically more representative of the data mass. However, the large amount of data stack will bring the effects of data fluctuations closer to the average value. This situation will cause the effect of short-term variable data to not be observed. Therefore, a suitable solution would be to reduce the data in the data stack to the minimum size that will represent the stack.

Table 4. The sorted list of class from lowest to highest data loss
Çizelge 4. En düşükten en yüksek veri kaybına kadar sıralanmış sınıf listesi

Classes	2420 Mhz	2440 Mhz	2460 Mhz	2480 Mhz
Temperature	5<1< 4< 2< 3	4< 3< 2< 5< 1	5< 4< 3< 2< 1	2< 1< 4< 3< 5
Humidity	3< 4< 1 < 2	3< 2< 4< 1	4< 2< 1< 3	4< 2< 3< 1
Precipitation	4< 1< 2< 3	4< 2< 1< 3	4< 2< 1< 3	4< 1< 2< 3
Wind Speed	4< 3< 1< 2	2< 1< 3< 4	4< 3< 2< 1	2< 1< 3< 4
Atmospheric Pressure	1< 3< 4< 2	1< 3< 4< 2	1< 3< 2< 4	2< 3< 4< 1

CONCLUSIONS

According to the study results, there is a positive relationship between temperature and wind speed values with data losses in the data transmission and a negative relationship between relative humidity values. According to the results of the study, relative humidity has a significant effect on data losses in wireless data transmission at 4 different frequencies (2420, 2440, 2460 and 2460 Mhz). Temperature has no effect on wireless data transmission losses at 2440 and 2460 MHz frequencies. When the temperature, humidity, precipitation, wind speed and pressure factors are evaluated together, 2460 Mhz wireless data transmission frequency can be preferred.

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Statement Contribution of The Authors

Authors declares the contribution of the authors is equal.

Statement of Conflict of Interest

Authors have declared no conflict of interest.

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