Performance of IEEE 802.11a and 802.11b Networks

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Abstract

In this paper we compare the performance of IEEE 802.11a and 802.11b networks in terms of throughput. We also compare the performance of different wireless adapters and transmission base units in terms of throughput and reachability. Finally, we study the influence of transmission location on the performance of these systems. We conclude that 802.11a systems appear to be faster and reach further than 802.11b systems.

Introduction

During the Spring 2003 term, the University of Minnesota, Morris is offering a Wireless Data Network course for the first time. One of the controversies in the wireless local area network world is, what protocol is best IEEE 802.11a or 802.11b? To settle this controversies, we set out to test both protocols using consumer grade, off the shelf receivers and transmitters.

To determine the significant factors that could affect the performance of these protocols, we established two different locations for the transmitters and four different locations for the receivers. We purchased two different laptop computers and five different wireless adapters to test with. The wireless adapters used PCMCIA, PCI and USB interfaces. We also requisitioned a used desktop computer to serve as a client.

The test was based on transferring a 108-MB file and determining the time that it took to download the file. To check the integrity of the received file, a checker program was run on both the sent and received file and any discrepancies were noted in the data. A couple of used desktop computers were configured using Linux and were used as the servers to download the file from.

This project was a joint effort between the Wireless Data Networks computer science class and Applied Nonparametric Statistics class. The classes were divided into groups and the goal was to have 2 computer science students and 1 statistics student in each group. As the term progressed there were some minor changes in the groups.

Once all the servers, transmitters and receivers were configured and tested, the various groups started to collect data. Once all the data was collected, the statisticians in the group took over and helped us analyze the data.

Description of the Experiment and Equipment

The main factor of the study is the protocol with two levels, IEEE 802.11a and 802.11b. Performance of these protocols is controlled by taking, transmission and receiving locations, and receiving equipment. The experiment has been replicated eight times. The details of the design of experiment are given in the following chart.

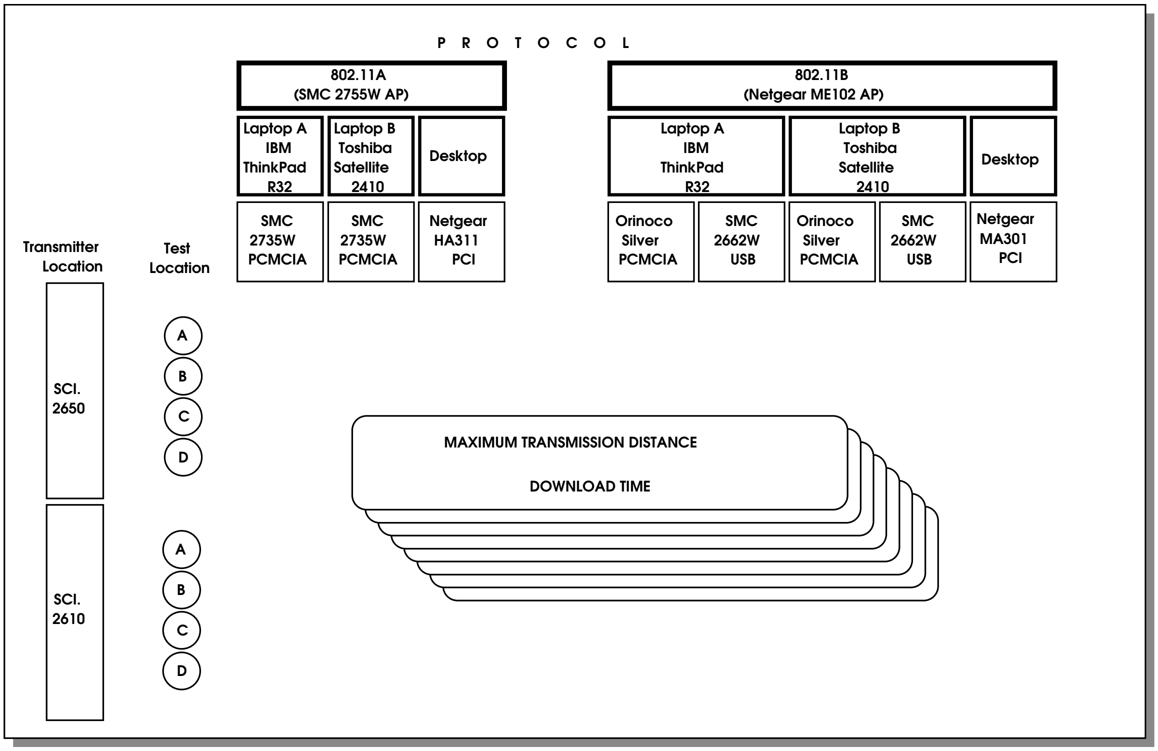

Figure 1. Design of experiment for the study.

Transmission locations

Two transmission locations were established. They were in the computer science labs labeled Science 2610 and Science 2650. Each room has shelves located near the ceiling in corners of the room with power and network access. In order to avoid interference with other network traffic, each transmitter was directly connected to a dedicated server near it.

Receiving locations

The receiving locations were established in a two-phase process. During phase 1, we established six widely dispersed locations within our building complex following some of the documentation in the literature. After some preliminary investigation, we determined that four out of these six receiving locations would not be reachable at all. All locations were within 100 m of the transmitters. During phase 2, we established four locations considerably closer to the transmitters than originally intended.

The computer science portion of the Science building is a four-floor brick building with steel reinforced concrete floors and mostly cement block walls. The building has a number of mechanical structures near the transmitting locations for an elevator, plumbing and heating and ventilating pipes. The authors believe that these mechanical structures created a severe impediment when trying to receive signals as close as 25 m from the transmitters.

After some trials, we established a test receiving location on each floor of the building approximately above or below the transmitters. The transmitters were located in the second floor and receiving location B was located 15 to 25m's south of the transmitting locations. The other receiving locations were labeled A in the first floor and C and D in the upper floors. Each receiving location was near a power outlet in the hallway of the building.
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Test Equipment

We purchased two Access Points (broadcasting units) - an SMC 2755W AP that uses the IEEE 802.11a protocol and a Netgear ME102 AP that uses the IEEE 802.11b protocol.

Three client computers were used in the receiving end. Two of the computers were laptops – an IBM ThinkPad R32 (labeled Laptop A) and a Toshiba Satellite 2410 (labeled Laptop B) each running Windows XP/Home and an older Micron desktop running Windows 98. All the client computers were reasonably configured with fast CPUs (e.g. 1GHz Pentium IV) and, at least, 256 MB of RAM to keep up with the wireless adapters.

Five wireless adapters were purchased for this class. The two PCMCIA adapters to be used with the laptops were an SMC 2735W to receive 802.11a broadcast and Orinoco Silver that uses the 802.11b protocol. A USB adapter, SMC Model 2662W that uses the 802.11b standard was also used with the laptops and desktop computer. In addition two PCI adapters were used with the desktop computer, a Netgear MA301 that uses the 802.11b protocol and a Netgear HA311 that uses the 802.11a protocol.

Procedures for conducting the tests

The following steps were typically taken when conducting tests. The group would sign out the equipment for a 2 to 4 hour block of time and conduct as many tests as possible during that time. A high precision Fisher Scientific stopwatch was used to time the downloads. To make sure that disk drive read speed was not a factor, the large file was preloaded into the memory of the Linux server. To avoid interference between transmissions, only one download from a given server was conducted at a time.

If the download test was successful, the download time was recorded. A successful download meant that the file was received in a timely fashion and the checksum of the received file matched that of the transmitted file. On a number of occasions, no suitable connection was established and those times were recorded as missing data.

Following our statistical consultant's recommendations, once the receiving and transmitting equipment was working properly, each group conducted a single test for that equipment configuration for that particular transmitting and receiving location. If the download failed half way through the process, it was recorded as missing data. If an operator error was detected part way through the process, the test was repeated.

Results

Each group of students collected 64 readings for a total of 512 readings. Of these 512 readings 273 were successful readings. Figure 2 presents a classification tree of the most influential factors of the successful transmissions. The first level of the tree indicates that protocol was the most influential factor, with 200 of the 273 successful readings coming from protocol 802.11b transmissions. The mean download time for the 802.11a protocol was 118.1 seconds vs. 279.2 seconds for the 802.11b protocol.

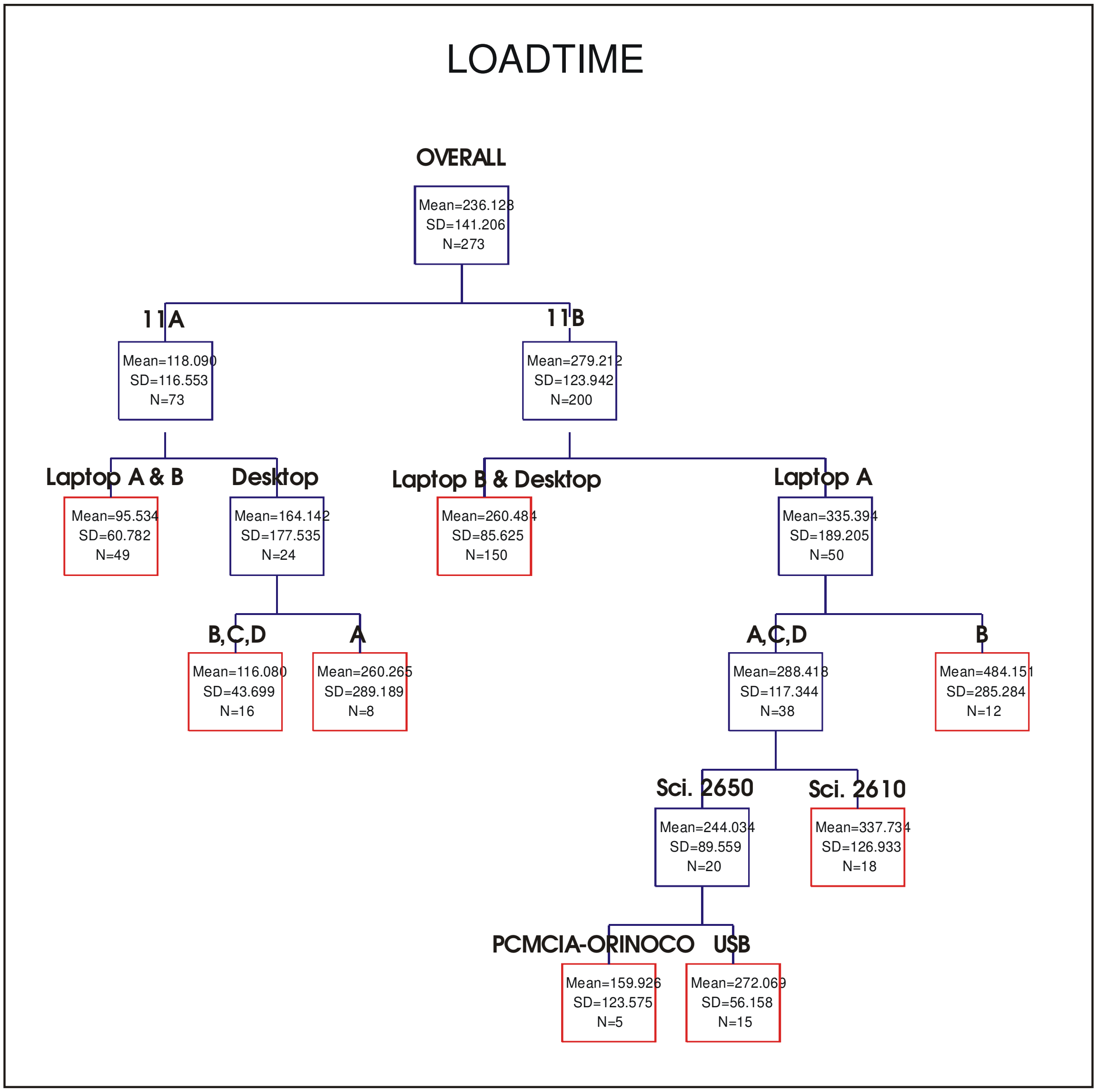

Figure 2. Classification tree for the load time.

The second most influential factor was the type of client computer used during the test. Using the 802.11a protocol, the laptops were considerably faster than the desktop. The laptops averaged 95.5 seconds for the download vs. 164.1 secs for the desktop computer with the PCI adapter. Using the 802.11b protocol, laptop A (the IBM ThinkPad) proved to be the slowest with average download times of 335.4 secs vs. an average of 260.5 secs for laptop B and the desktop computer combined.

The third most influential factor was receiver location. Under protocol 802.11a, location A (lower floor) was considerably slower (260.2 secs) than the other floors (116.1 secs). Under protocol 802.11b, location B (second floor) was considerably slower (484.1 secs) than the other three locations (288.4 secs).

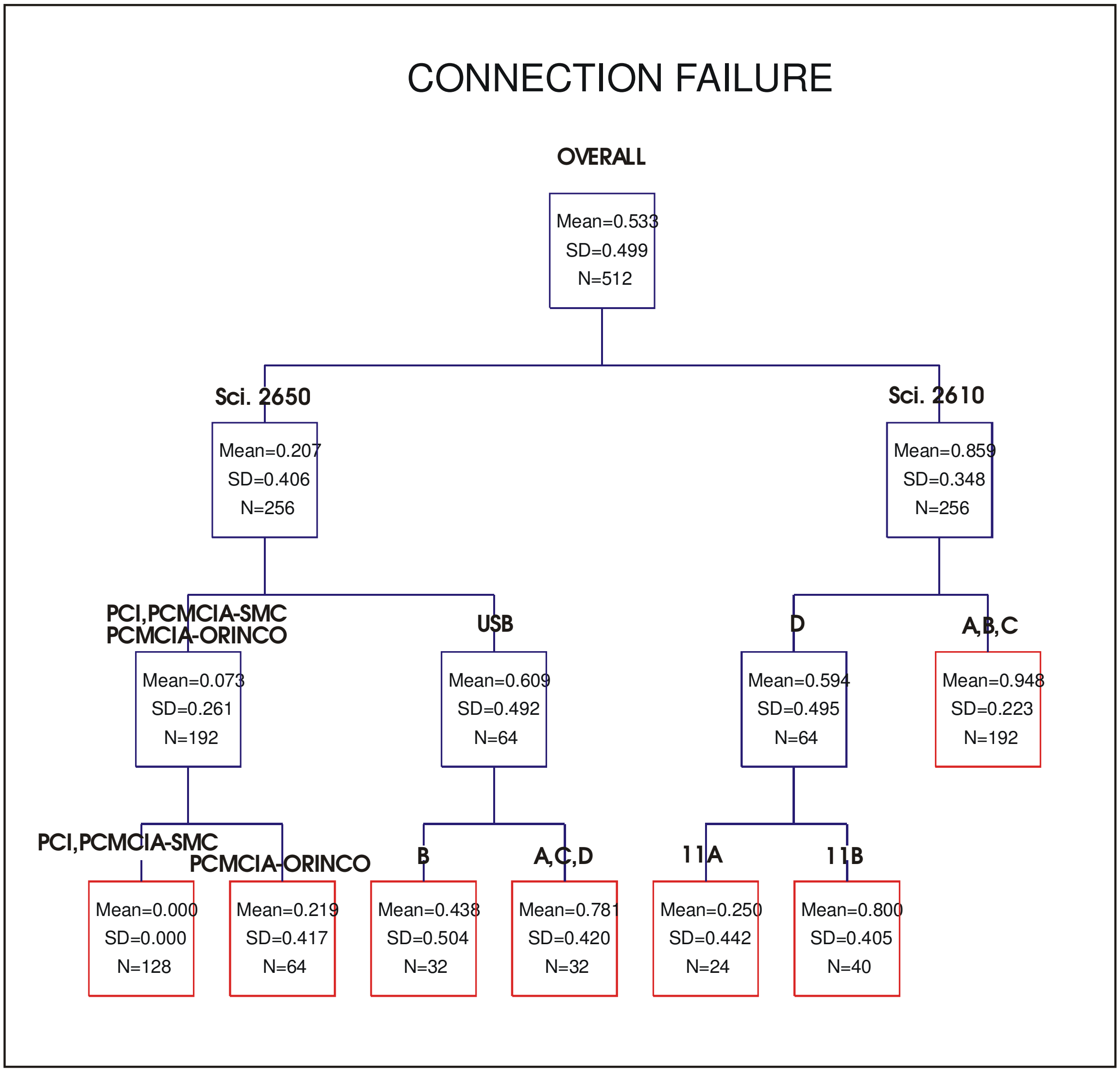

Figure 3. Classification tree for the connection failures.

Under protocol 802.11b there was also significant difference between transmissions from Science 2610 and 2650 and in the case of transmissions from Science 2650, there was marked difference between the performance of the PCMCIA Orinoco adapter and the USB adapter.

Figure 3 depicts the situation for the all the data including the missing data cases. In this case transmission location was the most important factor. Receiving location was the second most important factor in the case of transmission originating from Science 2610. Adapter type was the second most important factor for transmissions originating from Science 2650.

Based on the ANOVA model, protocol and receiving equipment interaction is statistically significant (p-value=0.001). Even though all the receiving units performed better under protocol 11a than 11b, the difference is significantly higher for the Laptop A compared to Laptop B and the desktop. See Table 1 and Figures 4 and 5.

Source	Sum-of-Sq.	df	Mean-Sq.	F-ratio	P
	1386				
Protocol	440.663	1	1386440.663	99.168	0.000
	2958				
Receiving	4.224	2	14792.112	1.058	0.349
	2034				
Prot.&Rev.	18.579	2	101709.289	7.275	0.001
	3732				
Error	851.353	267	13980.717		

Table 1. ANOVA Table for the best fitted model

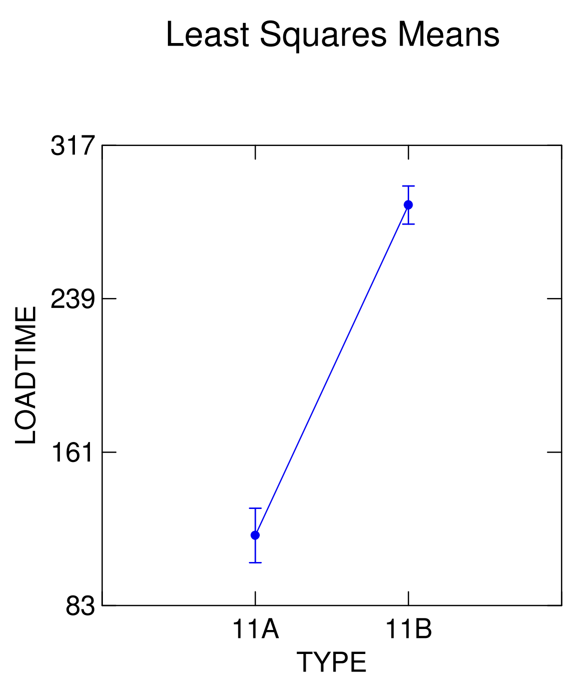

Figure 4. Protocol effect on overall loading times

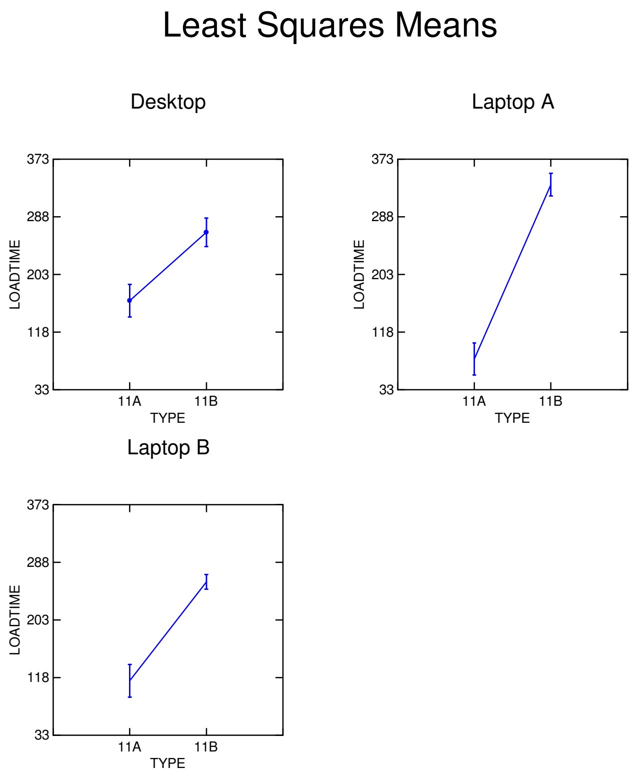

Figure 5. Protocol and receiving equipment interaction on loading times

The design of the experiment allowed us to compare the performance of the Orinoco Silver and USB adapters for the protocol 11b. The difference between mean loading time for these two adapters are statistically significant (p-value 0.008). The average loading time for the USB adapter is shorter than the Orinoco Silver. See Table 2 and Figure 6.

Source	Sum-of-Sq.	df	Mean-Sq	F-ratio	P
Adapter	126617.599	1	126617.599	7.205	0.008
Error	2917374.933	166	17574.548		

Table 2. ANOVA Table for the adapter type effect for 802.11b

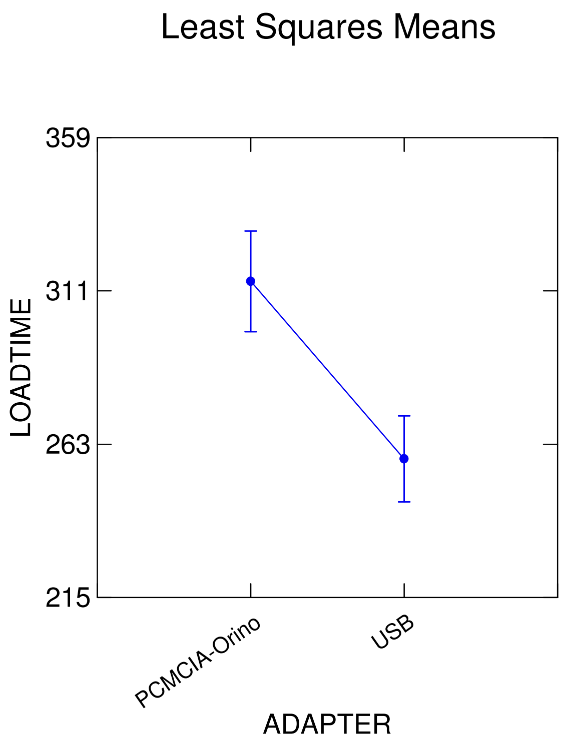

Figure 6. Adapter type effect on loading times for 11b protocol

Conclusions

The data demonstrates conclusively that the 802.11a protocol operating in the 5 GHz frequency has faster transfer rates than the 802.11b protocol that operates in the 2.4 GHz frequency. The proponents of these protocols claim transmission rates of up to 54 Mbps and 11 Mbps respectively. While our tests did not achieve these maximums, we did observe an average 3.87 Mbps for the 802.11b transmissions and an average 9.15 Mbps for the 802.11a transmissions. This represents a significant 2.36 time speed up for the 802.11a protocol over the 802.11b protocol.

The research team was disappointed that we could not achieve transmission distances of over 25 meters within our building with either protocol or any of the adapters. Later on this semester we plan to conduct some distance tests outside of our buildings.

We observe that many of our measurements had a relatively high standard deviation, which indicates a relatively high scattering of the data. For example, this was present when using the desktop computer under protocol 802.11a and most specifically at location A.

Based on our measurements, we conclude that most of the distance and transfer rate information that appears in the literature seems to be highly idealistic.

Acknowledgement

We acknowledge the cooperation of the whole Csci 4406 and Stat 4651 classes that worked many hours to collect the data reported here. Five students deserve special mention; Russel Kerfeld and Aaron Price helped the instructor set up some of the wireless equipment and servers during the fall semester. Dan Markert selected the file to be downloaded and the test for its integrity. Dan, Joel Nelson and Dan Wespetal helped setting up the equipment and creating the testing protocol. Finally colleagues in our physics and biology discipline loaned us stopwatches and distance measuring equipment. Thank you to all of you.