Using Connection Information between Mobile Devices and a WLAN to Create Digital Art

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ABSTRACT
With wireless hotspots becoming increasingly common and with more and more people owning at least one wireless device, which makes use of such a hotspot, a lot of connections between devices and access points in a wireless network are made. Information from these connections between wireless devices and access points can be collected. The paper will look at the information collected from such a wireless network. In this paper the collected information will be analyzed looking at the distribution of connections from the wireless devices to access points in the wireless network and tries to determine the mobility pattern of a wireless device which is connected to the network. This paper will then describe how the aforementioned distribution of connections from the devices to access points will be incorporated into a piece of digital art.

Keywords
Ubiquitous Computing, Digital Art, Wireless Networks, Mobility Patterns

1. INTRODUCTION
Nowadays it has become increasingly common that every location has a WiFi hotspot [1]. It is also the case that most people carry around wireless devices such as smartphones and laptops which have WiFi connection capabilities. This means that people can connect to wireless networks wherever they are. From a wireless network made up of WiFi hotspots it is possible to obtain connection information about the devices which connect to access points in the network. This is information such as the IP and MAC address of the device, as well as the time and duration of the connection to an access point.

The obtained connection information, which in this paper is referred to as raw connection data, can give interesting information about the users of the WLAN. In order to find out more about the WLAN and the users an analysis has to be done of the raw data. There are several aspects of the raw connection data which can be analyzed. In the case of this paper the focus will be on determining the mobility patterns of devices connected to the wireless network. The mobility patterns will try to show the distribution of wireless devices between access points over time, as well as a general direction of a wireless device over time.

The mobility patterns will be determined by processing the raw connection data. The process will sort the raw data into a new data set and make it possible to easily determine the movement of a wireless device between access points. Another data set will also be created which can be used to determine the number of connections to an access point.

The results of such an analysis of the raw connection data can be applied to everyday use in several different ways. In the case of determine mobility patterns there are aspects which could provide useful for security reasons. Another application could be in determining frequently travelled paths and optimizing the layout of a building. In this paper the results will be incorporated into digital art. Digital art can widely be defined as a general term to describe a range of artistic work that uses digital technology [2]. In this paper digital art will be a computer program that incorporates the results of analyzed data and gives a graphical representation of these results.

This paper will start by explaining the problem statement and proposing research questions in order to come to a conclusion on the problem. Following this each research question will be examined and in the conclusion the research questions will be reflected upon. In the conclusion the outcome of the research questions will also try to give an answer to the problem statement.

2. PROBLEM STATEMENT
The goal of this research paper is to analyze the raw connection data to determine the mobility pattern of devices using the wireless network and determine the distribution of connections over time. Once the analysis is done the secondary goal is to incorporate the results of the analysis into digital art.

2.1 Research Questions
The research questions, which are needed to address the problem statement, are as follows:

1. What type of raw connection data between wireless devices and access points can be collected?
2. What are the implications of the raw data and how can it be processed into useful data?
3. How can the processed data be incorporated into digital art?

2.2 Approach
This paper will look at two aspects of the connection data between wireless devices and access points. The first will be the distribution of connections between access points over

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time. The second will be to try and determine the mobility pattern of wireless devices using the connection data. The results of this information will then be incorporated into digital art as a way of displaying the results.

The approach to answering the research questions shall be a practical one. Five steps have been created to help with this process. The first step is data collection, this leads to the second step which is the raw data which goes directly into the third step which is filtering the raw data. After the third step comes analyzing the data, and the final step is applying the analyzed data. The first three steps of this process correspond to the first research question. Here the focus is on collecting the data and determining what is required of the data. The forth step, analyzing the data, corresponds with the second question. In this step the raw data will be processed and analyzed in terms of mobility patterns and distribution connections between wireless devices and access points. The final step corresponds with the third question. In the case of this paper the application of the analyzed data will be to incorporate the results of the analysis into digital art.

3. DATA COLLECTION
The first step is collecting the necessary data to do an analysis on. In this section the first phase of the research, which correlates to research question one, will be discussed.

3.1 Requirements of the Data
In order to effectively analysis the mobility patterns and distribution of wireless devices to access points in a WLAN there have to be minimum requirements to the raw data set. Also a certain amount of information has to be available in the raw data. The following requirements were given to the raw data.

3.1.1 Data Format
The raw data has to be formatted in a way which values are comprehensible and measureable. If this is not the case then it will not be possible to use the data for the analysis.

3.1.2 Number of Connections
The number of connections is the number of times an access point registers a connection to a wireless device. A certain amount of data is required in order to make an accurate analysis. The number of access points is also important. In order to see movement at least data of connection to two access points are needed. The number of connections is dependent on the number of access points and the time span in which the access points are monitored.

3.1.3 Real Time vs Delay
The benefit of real time is that the results of the analysis can be compared to the actual live environment. This also means that the results are live which for applications such as a security application can be very important. There are drawbacks however, the first is that depending on the network administration the necessary information cannot be provided real time because the administration software is not real time.

Another drawback specific for this paper is that if the raw data were to be provided real time it would not matter. This is because in order to measure the distribution over time the data has to be collected for several periods of time; this in itself requires a delay. For determining movement patterns a delay is also desired. This is because it can be the case that devices are connected to one access point for a relatively long time and sparsely move between access points. This would mean that a lot of time during the analysis would be spent waiting for meaningful data to come in. If there was a delay then a whole data set could be provided in one go. Therefore in this research it was chosen to have a delay in the raw data, this means that a set of data was obtained in one go.

3.1.4 Layout of Access Points
In order to determine the movement pattern of a device it is required that one knows the layout of the access points. This means that along with the raw connection data a layout of the access points also has to be obtained. Figure 1 shows the layout of the access points used in this paper.

![Figure 1. Layout of access points](image)

The access points in figure 1 are named as follows: inf-h3-2, inf-h3-4, inf-h3-5, inf-h3-6 and inf-h3-8 from left to right respectively.

3.2 Data Set
The raw connection data used in this paper contains the following information about each connection made to an access point.

- IP and MAC address of the device
- Username of the device
- Vendor of the device
- ID and location of access point
- Time connected to access point
- SSID of the device
- Duration of connection to access point
- Session throughput in Kbps
- Upload and download in bytes

Some information such as the throughput and up- and download will not be important for the analysis in this paper. This information will be filtered later on. It is important to note that this information is only about devices connected to the access point. A device can only be connected to one access point at a time. So this means that for a unit time we can only see which access point a device is connected to. It will therefore not be possible to determine the exact location of the device [4]. In order to do this we need to know which access points can see the device and know the signal strength of the connection.
3.3 Obtaining the Data
The raw data for this paper comes from the wireless network on the campus of the University of Twente. The data comes specifically from the access points on the third floor of the Zilverling building. The data was provided by ITCS [3], which is the faculty in charge of the network administration at the University of Twente. The raw connection data contained 403 connections made to the five access points on the third floor. The time span of this data was 1 day.

3.4 Filtering
Once the data is obtained the next step is filtering the data. In this step the raw connection data, which is extracted from a database to a .csv file, is read into a Java program and filter, so that only the necessary information remains.

In order to determine distribution and mobility patterns one needs to know the following; identity of the device, identity of the access point it is connected to, time connected and duration of the connection. For the identity of the device it was chosen to filter by MAC address because these are always unique. An IP address can easily change especially with wireless devices which often disconnect then reconnect without a set IP address. To identify the access point the access point id was used. The location of the access point is also given in the raw connection data but this only gives the building and floor on which the access point is located which is not specific enough to determine the mobility pattern of a device between access points on the same floor.

Not only is the unnecessary information filtered out of the data at this step, the necessary data is also formatted in a way which will make the analysis easier. Time values are changed from String objects to Double objects in Java. This will make it easier to sort the data by time and make it possible to do mathematical equations with the Time.

4. DATA ANALYSIS
4.1 Goal
The goal of the analysis is to determine the mobility patterns of devices connected to the wireless LAN on the third floor of the Zilverling and to give a distribution of the number of connections to the five access points per unit time.

The mobility pattern in this case will be the direction of the device, which correlates to the direction of the owner of the device. Due to the fact that the exact locations of the access points are not known and we cannot determine the exact location of a device it will not be possible to determine the movement speed of a device for this research.

The expectation of the results of this analysis is that one will be able to see how users move along access points. This will give the direction of the user. Another expectation is that one will be able to see a correlation between the distribution of connections and specific times at which it is expected that users of the network will significantly increase or decrease. These times are: start of the day, coffee break, lunch time and end of the day. It is expected that these times will show up clearly.

4.2 Method of Analysis
In order to determine the direction of a device one has to look at which access point the device was connected to and see which access point it is currently connected to. This, along with knowing the location of the access points will indicate the direction of the device, if it is moving.

To determine the distribution of connections between access points over time one needs to look at each access point individually. Then for each access point it needs to be determined which devices are connected at what time. Once this is known it is possible to group connections by units of time, for example an hour or 5 minutes, and then count the number of connections each access point has at that time.

Before this can be done the filtered connection data which was discussed in section 3.4 has to be sorted correctly. By sorting the data it will be possible to easily obtain the needed information for the analysis. The filtered connection data is sorted into lists using 3 simple naive sorting algorithms which are discussed below.

4.2.1 Algorithms
4.2.1.1 Sort by Access Point
This algorithm is used to sort all the filtered data by access point. It looks at the access point id of a connection and depending on the id, it places the connection data into a list with all the other connection data to that access point. This is needed when determining the distribution of connections per access point.

4.2.1.2 Sort by MAC Address
This algorithm sorts the filtered data by MAC address. For each MAC address a new list is made. The algorithm looks at the MAC address of connection data and sorts it depending on the value of the MAC address. This is needed when looking at the mobility pattern of a device. Each MAC address will have a list showing the connection data for each connection it makes to an access point. It is important to note that in this case the access point is not unique to the list but instead it is unique to time. So a device with a MAC address can be connected to the same access point several times but it cannot be connected to several access points at the same time.

4.2.1.3 Sort by Time
This algorithm is used to sort lists by time. This algorithm can be applied to the lists generated from the first two algorithms. This algorithm looks at the time connected of a connection and reorganizes the list according to the time the device connected to an access point. This is important for both the distribution of connections and the mobility pattern of a device because both depend on time and in order to determine something the previous connection as well as the current and next connection has to be known. This can easily be determined by sorting by time.

4.2.1.4 Time Disconnected
In addition to the information from the three sorting algorithms there is also one more piece of information which has to be determined. Time disconnected is information which is not directly given in the raw data. It is however possible to determine the time a connection to an access point ends. This information is useful to know when looking at an individual device connecting to access points over time. The time disconnected can be calculated by adding the session duration to the time connected which are both known values.
4.2.2 Application of Algorithms
4.2.2.1 Distribution of Connections between Access Points

To make an analysis on the distribution of connection between access points the filtered data has to be sorted first by the sort by access point algorithm. This gives 5 lists, one for each access point, which have to be sorted by time. This is done by using the sorting algorithm discussed in 4.2.1.3.

After the lists have been sorted the data has to be presented in a way which can be easily understood. A small algorithm is used to split up the lists by a unit time (which has to be given) and then prints the result. The full results of the distribution of connections to access points per hour can be seen in Appendix A. Figure 2 shows the distribution for access point inf-h3-2 and inf-h3-4 respectively per two hours as printed by the Java program used to sort and analyze the data.

Figure 2. TUI display of the distribution of connections to the first two access points.

4.2.2.2 Mobility Pattern of a Wireless Device: Direction

The filtered data has to be sorted first by MAC address which can be done with the algorithm described in 4.2.1.2, then each result has to be sorted by time using algorithm 4.2.1.3. When this list is printed it will give a result such as figure 3.

Figure 3. TUI display of a client moving between access points.

Figure 3 shows the connection time, disconnection time and access point respectively for each connection the device makes. From data such as figure 3 and a layout of the access points such as figure 1 it becomes trivial to determine the direction of a device.

4.3 Results
4.3.1 Distribution

The results of the distribution of connections the access points over time are shown in appendix A. It was expected that it would be clear to see at least 4 points in time were a large difference in the numbers would be visible. Two of these points in time were the start and end of the day. Both of these can clearly be seen. Work starts at 8 o’clock and at 7 o’clock we see the first device connect to the access points. The same goes for the end of the day. Work ends at 18 o’clock and the last connections are seen at 19 o’clock. The last two times are the coffee break, which is traditionally around 10 o’clock, and the lunch break which is between 12 and 13 o’clock. In the results there is no abnormal shift at around 10 o’clock. As for the lunch we see that the number of connections greatly increases between 12 and 13 o’clock.

A reason that the coffee break at 10 o’clock is not visible in these results could be that the unit time is taken too large. It could be that there is a movement between access points but that it is all within an hour which means that a large change in the overall distribution would not occur. What would change is the total number of connections. This is because moving between two access points creates 3 connections. First a connection to access point one then to access point two then back to a connection to access point one. We do see an increase in total number of connections but not large enough to show abnormal amounts of movement. It could be the case that people prefer to leave their wireless devices at their desks when taking a coffee break.

Around the lunch break and into the early afternoon there is an increase in total amount of connections. There also seem to be more connections to access point AP2 (inf-h3-4) and AP4 (inf-h3-6). It is important to know that the entrances to floor 3 are at those access points. This could mean that we see people while leaving their desks to go to lunch connect to the access point closest to the door before leaving floor 3.

4.3.2 Direction

There were 189 unique MAC addresses. Many of these devices only connected to one access point. This means that they did not move from their start location. The reason behind this could be that the devices are stationary yet wireless. An example would be a laptop which is wireless but is only turned on when sitting at a desk and is only moved around when turned off. Results of some of the more mobile devices can be found in Appendix B. The MAC addresses are covered but it is possible to distinguish between cases by looking at the number after the covered up MAC address.

Finding the direction is trivial so this is not always interesting to look at. What is more interesting is the movement itself. The most interesting to note is that connections often skip an access point. An example of this can be seen in figure 3 were the device moves between access point inf-h3-5 and inf-h3-8. In between these access points is inf-h3-6 but the device does not connect to this access point. A reason for this could be that the range of the access points overlap and the max radius of an access points is larger than the distance between access points.

4.3.3 Limitations

There were a few limitations to the data. The first and probably biggest limitation was that there is also a floor above and below the third floor of the Zilverling both with access points to the same WLAN. This means that at any point in time a device could connection to an access point not on the third floor while moving, or even when stationary keep switching between access points on different floors. This limitation in the data could be the reason why in Appendix B devices disconnect from an access point for a few minutes only to reconnect to the same access point again. During this in between time the device might be connected to an access point on a different floor.

Another limitation is applicable to the distribution of connection per access point. For this analysis it was chosen to
look at the number of connection per hour. However the MAC address of a connection does not have to be unique within a unit time. This is because a device can connect to for example access point one then move to access point two when getting some coffee then move back to access point one within an hour. The drawback however is that it could also be the case that the device has not moved at all but just reconnected to the access point. This means that the number of connections to an access point will generally be greater than the actual number of connections that happened. This limits the accuracy of the results.

A final drawback which applies to the distribution of connection is that a device is not traceable. This is not so much a limitation of the data but more a limitation of the implementation. The problem here is that when one access point gains a connection and another access point loses a connection it does not have to mean that the same device is responsible for both the connection and the disconnection. It could also be the case that one device disconnected and another device joined the network. This again limits what can said about the data.

5. AN IMPRESSION

As mentioned in the introduction and later in section 2 a use of the results of the analysis in section 4 is to use it in creating digital art. For this research a small proof of concept was made to give an impression of what is possible with incorporating the analyzed data in digital art. The proof of concept uses the results from the distribution of connections between access points. In this case the digital art is a Java program which attempts to visually show the change in distribution over time. Figure 4 and 5 show the program at two stages. Figure 4 is the distribution at time 13:20 and figure 5 is at time 13:40, which for the program is the next unit time.

![Figure 4. GUI display of connections of wireless devices between access points at time 13:20:00.](image)

![Figure 5. GUI display of connections of wireless devices between access points at time 13:40:00.](image)

Each ellipse in the program represents an access point starting at inf-h3-2 on the left up till the fifth access point inf-h3-8 on the right. The number in the ellipse is the number of connections to that access point at that time. The program changes in increments of 20 minutes. The x- and y- size depend on the number of connections to the access point. Also if there has been an increase in the number of connections to an access point then the size of the x axis is increased by 1.2 and the size of the y axis is decreased by .2. If there has not been an increase then the size of the y axis is increased by 1.2 and the size of the x axis is decreased by .2. An example of this principle can be seen in figure 4 and 5. There has been an increase in the number of connections in each access point except the 4th, this means that those access points will have a larger x axis size. The numbers of connections to access point four have decreased, so the size of the y axis is longer. Using this same principle we can also see that in figure 4 that at time 13:00:00 access point four had 6 or more devices connected to it.

6. CONCLUSION

6.1 Research Questions

What type of raw connection data between wireless devices and access points can be collected?

The data collected consisted of purely data about connected devices, the exact information can be found in 3.2. This was enough information to be able to make a distribution of devices connected to access points over time and to determine the direction of a device if it was travelling. However there was not enough information in the data to determine the speed or exact position of a device.

The type of raw connection data depends on two aspects. The first aspect is what is the goal of data? In this paper the goal was to look at mobility patterns. So depending on what aspect of the data is going to be analyzed the type of data will be different. The second aspect is what data can be obtained, it can be possible that certain information is not available consequently another way to obtain the needed information has to be found.

What are the implications of the raw data and how can it be processed into useful data?

This question comes down to how can the data be analyzed and what is the meaning of this analysis. This aspect was discussed in section 4. The implications in the case of this paper were the mobility patterns of devices and the distribution of connections to access points over time. It was possible to create a distribution of connections to access points and it was possible to determine the direction of a device. However these results were limiting. This means that the results may not be very useful. In order to get better results either the raw data set would have to cover the entire network which would mean a lot of data, or the network would have to be restricted to only the 5 access points which were used in this paper.

The way the raw data was processed into meaningful data was by sorting the data using simple, naive algorithms. Once the data was sorted into organized lists it was only a matter of separating the data. In the case of the distribution of connections to access points the data had to be separated by
access point then by time. For the direction of a device the data was separated by device.

**How can the processed data be incorporated into digital art?**

This research question looks at the application of the processed data. The processed data is the result of the analysis done for question two. In the proof of concept it was shown how the distribution of connections to access points over time was incorporated into a program. This program would draw the distribution as ellipses which would change depending on the number of connections to an access point and if there was an increase in connections or not. This shows a simple method of incorporating the processed data into digital art.

**6.2 Improvements**

In section 4.3.3 the limitation of the data was mentioned. An improvement to the results for the analysis would be to have a more complete data set. This means the results of the analysis would be better if the data covered the whole wireless network. 5 access points seem to be a good number of access points because it gives enough varieties but keeps the amount of data low enough to not lose the overview. This would mean that the wireless network would have to be restricted to only the access points one floor 3.

**6.3 Future Works**

An extension of this paper would be to look at other aspects of the mobility pattern of a device, aspects such as speed or exact location of a device. In order to achieve this the raw data set would have to be expanded. Another addition would be to extend the digital art. In the paper only a simple impression is given. However the possibilities for incorporating the processed data into digital art are vast which leaves a lot of options for improvement or variety. Finally digital art is only one way of applying the analysis of the raw data. An interesting research would be to look at what other possibilities there are and what other uses can be found.

**7. REFERENCES**

APPENDIX

A. Distribution of Connections to Access Points per Hour

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*Note AP1 corresponds with inf-h3-2 etc.

B. Mobility Pattern of Devices

Hier de data van: 13
0: 10:42:08 : 10:44:35 : inf-h3-5
1: 10:49:15 : 10:51:19 : inf-h3-8
2: 11:58:09 : 11:59:35 : inf-h3-8
7: 15:29:55 : 15:36:30 : inf-h3-8
8: 16:29:56 : 16:38:29 : inf-h3-8

Hier de data van: 14
0: 10:15:40 : 10:37:26 : inf-h3-8
1: 12:30:47 : 12:30:56 : inf-h3-4
5: 15:03:31 : 15:06:20 : inf-h3-8

Hier de data van: 38
0: 09:13:24 : 09:17:40 : inf-h3-4
2: 09:44:52 : 09:49:10 : inf-h3-4
4: 09:59:36 : 10:03:40 : inf-h3-4
5: 10:03:50 : 10:07:57 : inf-h3-4
6: 10:07:58 : 10:12:54 : inf-h3-6
Hier de data van: 09:05:33 : 10:04:44 : inf-h3-6
0: 09:05:33 : 10:04:44 : inf-h3-6
1: 10:04:45 : 10:43:21 : inf-h3-6
5: 11:56:37 : 12:07:09 : inf-h3-6
6: 12:07:09 : 17:11:14 : inf-h3-6
7: 17:11:40 : 17:15:06 : inf-h3-6