
Free-space Emulator of 60GHz Directional Antenna Equipment

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Abstract

millimeter-wave radio based indoor communication systems are promising to provide high data rate, in the order of Gbps, connections between communication devices. Using directional antenna has been proved as an effective way to reduce the effect of multipath propagation in millimeter-wave indoor radio channels at 60 GHz. Line-of-sight (LOS) is therefore required between the sender and the receiver. However clear LOS propagation has difficulties to guarantee the connection because human activities, i.e., human bodies, may block the propagation paths in indoor environments. Therefore it is important to study human activity behavior in order to gain insights on the 60GHz LOS link stability. We aim is to study the effect or the influence of human's activities on the 60 GHz line of sight(LOS) communications in an indoor environment in order to feed the future a general link stability model that can help as inputs for various network operation and decision-making functions to improve network performance. To study the effect of human bodies on the LOS Link by 60GHz, an optical emulator has been built. An infrared channel (Transmitter-receiver) used to measure the duration time when the LOS becomes unavailable due to human activity. Based on the measurement the Unavailable Rate (R) is calculated as one of the performance metrics for the future study. Further the collected data have been measured according to two majors scenarios and the collected data have been fitted in two different softwares to find out the result. Finally we customized a mathematical model and tested on the collected data in order to evaluate the goodness fit of the custom model comparing to the other two established distribution models.

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Chapter 1

Introduction

Narrow-wide bands measurements have been lately preformed in outdoor and indoor environments, and both measurement try to develop a modern prediction model for the 60 GHz radio channel. The huge need for a high bit rate in mobile terminal's services becomes necessary for developments in broadband radio networking. Outdoor and indoor broadband wireless systems can be used these days in different out-indoor environments such as hospitals, railway stations, malls and shopping center, even in the medical field video communications between the ambulance and the medical care specialist can have a great benefit in emergency situations.

The 60 GHz band, which is roughly between 57 and 66 GHz [1], has the property of being the atmospheric oxygen absorption band, which means for an outdoor environment that transmitted signals are strongly attenuated about 15 dB/km in addition to the free space loss [12]. The UHF band is not suitable for mobile broadband applications, broadband system with total network capacity of a couple hundreds of megabits per second will absolutely request therefore hundreds of megahertz of spectral space. Further high frequency bandwidths is only available at radio frequency above the 25GHz in term of considering a congest free bandwidth [7].

Above approximately 40 GHz, high density traffic can be reached, in indoor environment, due to the ability of interference with the neighboring rooms. The frequency in this case can basically be reused because of the intensive attenuation of electromagnetic waves at this high frequency, knowing the fact that usually in an indoor environment a single wall can separate two rooms.

The 60 GHz band can also be interesting for an indoor environment since that millimeters radio waves can pass through windows, and therefore they can also interfere with the neighboring systems in other neighboring rooms or buildings.

There are plenty of researching groups who have seen the huge demand to investigate the ability of having high data rate 60 GHz radio communications within indoor environments, therefore we consider their work as a great knowledge. Here we are briefly a list of some of the current interesting groups, researching and working on 60 GHz radio communications

- **IEEE 802.15.3c WPAN :**

The IEEE 802.15.3 Task Group 3c (TG3c) was formed in March 2005. TG3c is developing a millimeter-wave-based alternative physical layer (PHY) for the existing 802.15.3 Wireless Personal Area Network (WPAN) Standard 802.15.3-2003. This millimeter Wave WPAN will operate in the new and clear band including 57-64 GHz unlicensed band. In addition, the millimeter-wave WPAN will support high data rate at least 1 Gbps applications such as high speed Internet access, streaming content download (video on demand, home theater, etc). [16]

- **IEEE 802.11ad - Extremely High Throughput 60GHz and WiGig:**

More than 15 technology companies today announced the Wireless Gigabit (WiGig) Alliance, an organization formed to establish a unified specification for 60GHz wireless technologies. The widespread availability and use of digital multimedia content has created an ever-increasing need for faster wireless connectivity that current wireless standards cannot support. The WiGig specification will allow devices to communicate without wires at gigabit speeds within a typical room. There are already two groups looking at possible standards for 1Gbit/s wireless LANs, called 802.11ac and 802.11ad. The 802.11ad group is studying 60GHz technology, which the WiGig Alliance is also pushing for fast wireless connections.

- **Wireless HD Group**

The WirelessHD specification defines a wireless protocol that enables consumer devices to create a wireless video area network (WVAN) with stream uncompressed audio and video at up to 1080p resolution. A large amount of spectrum is available on an unlicensed basis in many regulatory domains in the 60 GHz band. The WirelessHD specification defines a novel wireless protocol that enables directional connections that adapt very rapidly to all changes in the environment [17].

- **EcmaT48 High Rate Wireless Communications**

Ecma T48 develops Standards and Technical Reports for high rate wireless communications. Ecma T48 is a high-speed wireless networking standard for use in the Television White Spaces: broadcast television spectrum not being used by licensed services at a given location [18].

- **(SiGi-spot) and Future Home networks (FHN)**

60 GHz radio technology for high-capacity wireless in-home communication networks (SiGi-spot) and Future Home networks (FHN) are dutch research projects researching on new network architecture and the feasible physical, link and network layer solutions for high capacity in-home communication and networking utilizing license-free 60 GHz band.

The goal of the SiGi project is to define a new low-cost radio technology that utilizes the license-free 60 GHz band.

FHN do research towards such a future-proof home network. It will be based on a communication architecture that uses very high bandwidth (order of Gbps) short-range transmission inside a room, and uses dedicated equipment and devices to cross walls, connect rooms and reach gateways for connection to access networks [14][15].

1-1 60 GHz Radio Channel Characteristics

In order to make use of unlicensed 60GHz frequency bands for high-bit-rate systems it is essential to determine or characterize the channel dispersion.

The performance of a system works on high frequency band can extremely effected by channel dispersion. As first we try to study the difference of the path loss and the directional of arrival between narrowband frequency at 60 GHz and at 1.7 GHz, then we will try to determined what if any consideration should be known or taken in advance that could effect severely the 60GHz system.[7]

1-1-1 Path Loss

Narrowband path-loss measurements have been lately performed at 60 GHz with a certain separation distance using a source and a spectrum analyzer. The antenna was narrow in the vertical plane and broad in the horizontal plane [7]. All measurements were performed with transmitter and receiver on the same floor. The direct path was blocked by the room furniture or using a kind of a light wall separator. Therefore a clear Line Of Sight (LOS) path was not always present in every measurement. In figure 1-1 the 60GHz path-loss have been dark highlighted to notice the different with 1.7GHz path-loss.

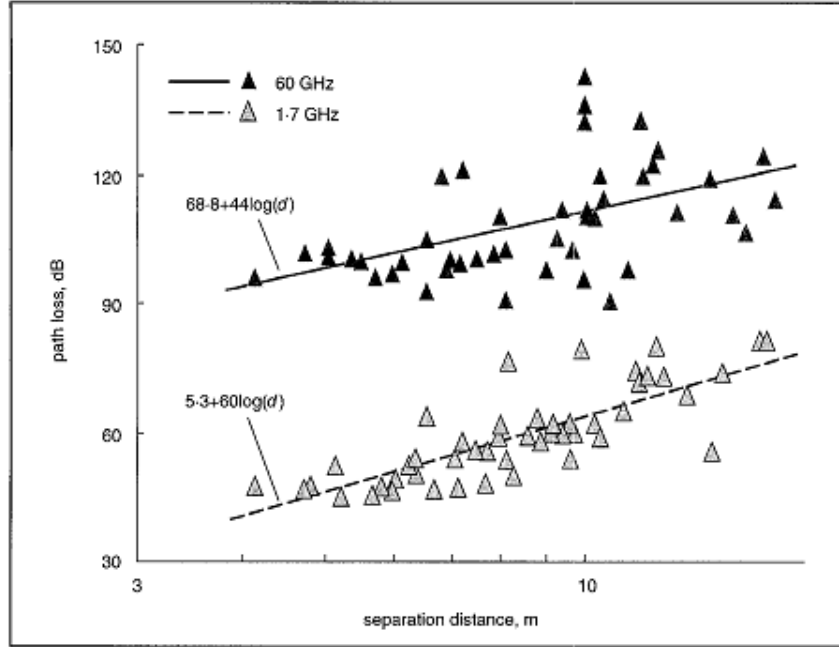


Figure 1-1: Path Loss Against Distance at **60GHz** and at 1.7GHz [7]

The path-loss in figure 1-1 is much higher at 60GHz even at higher separate distance, when the attenuation is the quite small. The difference in the free space partly can explain this result, the rest of the differences can be caused by material existence in the room or in the floor, the 60GHz millimeter wave can't penetrate the overall materials, plus the diffractions loss at 60GHz. The result of the narrowband indoor path-loss is that shadowing at 60GHz affect the performance of the channel and is obviously more severe than at 1.7GHz. Millimeter-wave radio based communication systems are promising to provide high data rate connections between communication devices. Although at these high frequency band the coverage will always be limited due to the transmission power boundary level and the free space propagation loss. Therefore the future research investment concentrate at indoor wireless communi-

cation coverage.

1-1-2 Direction-of-Arrival and Received Power

To investigate the individual signals paths and to find out the advances that can be reached or achieved using sort steered antennas, direction of arrival data have been created via plenty of measurements at 60 GHz using the same measurement system as for the previous path-loss measurements.

The difference in this measurement is have been made by using a receiver antenna had a narrow beamwidth but in both vertical and horizontal planes. The measurements show that in an indoor environment using steering antenna in the azimuth plane improve the 60GHz link [7].

Further dominant contributions to the received power occur from specular reflections.

Because of the high path loss at 60 GHz and the transmission power restrictions it becomes necessary to use directional antennas. Directional antennas have a higher antenna gain compared with omni directional antennas. This means that for the same transmitted power there will be a higher SNR at the receiver for directional antennas, however the use of directional antennas introduces challenges which do not arise when omni directional antennas are used[7]. The use of the directional antenna reduce the effects of the multi-paths propagations, further more the use of circular polarization instead of linear polarization will reduce the delay spread [9][8].

1-2 Human Shadow at 60GHz

Studying the path-loss and the direction of arrival made it quite clear that objects placed in the direct path of 60 GHz link will cause a shadow which in turns will reduce the performance of the channel. In indoor environments human's motion is a natural behaviour, and the link stability of the 60Ghz LOS depends in his turn on human activity. Therefore LOS propagation has also his own difficulties to guarantee the connection because of human activities.

1-2-1 60GHz Line of sight (LOS)

Humans body may block the propagation path in 60GHz in-door environments during their movements, basically a human being who walks between 60Ghz transmitter en receiver terminal can simply break the channel with his body and block the signal. Due to the block made by the human bodies, the signal level can decreases up to 20dB at the receiver terminal[2] and a single shadow occurs. A shadow can be created from peoples movements, breaking the link, causing significantly signal level decreasing at the receiver side. This leads to consider the channel unavailable during a shadowing event[2],[3].

The next figure,1-2, shows an example of a single shadow made by human blocking the propagation path of 60Ghz LOS at 90cm position, which is between the transmitter and the receiver, when the signal level significantly decreases about 20dB at the receiver terminal[4].

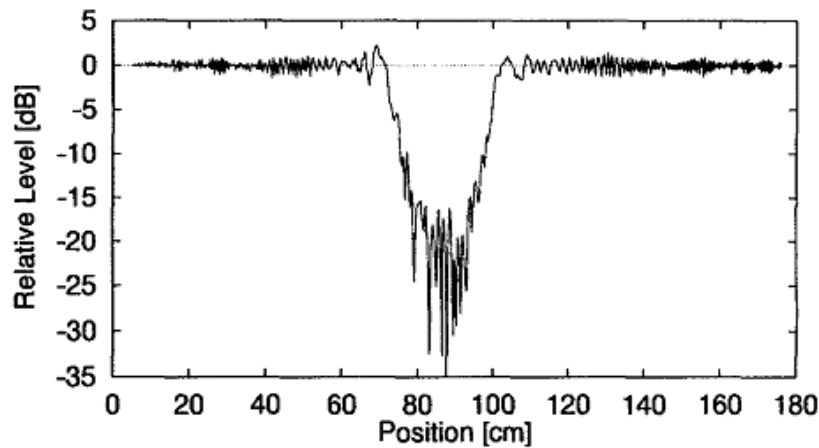


Figure 1-2: Single Shadow Event by human at 60Ghz band

It's quite important to study the propagations characteristic of the 60Ghz LOS in order to test the effect of human body on breaking the link, although the

shadow event has standard parameters that can determined the size and the duration of the shadow.

Before we consider the shadow events characteristics there are a couple of important definitions can be declared such as:

1. **Attenuation:** $A(t)$ is the ratio of the transmitted power before the sender antenna on the received power after the receiver antenna
2. **Temporal Fading:** $F(t)$ is the temporal variation of the $A(t)$ around a reference level $Aref$, [2]

$$F(t)_{[dB]} = A(t)_{[dB]} - Aref_{[dB]}$$

1-2-2 Single Shadow Event

When a 60Ghz link between transmitter antenna and the receiver shadowed by a person, the attenuation will certainly strongly increases, and these attenuation breaks are not uniformly distributed, simply because this process is not stationary. We can also characterize these attenuations breaks, (peaks), in amplitude and duration. A single shadow events can be created when $F(t)$ becomes greater than a predefined threshold, the threshold values can be determined between (5 up to 20)dB.[3].

The beginning of the shadow, Tb_{SE} , is the immediate point of the threshold crossing by positive slope. while the, Te_{SE} , is the instant of the threshold crossing by a negative slope. Determining the negative and the positive slope has a complex criteria issue but what we need to know is the duration of the shadow is basely how many seconds or Millie second took a person, or a group of people, to walk through a 60 Ghz link. From the stability point of view it means how many seconds or Millie seconds is the link unavailable, which give us an idea about how long the link can be broken for a certain period of time and how many times have been broken during a certain period of time. The duration of the shadow can be computed as follow, while figure 1-3, shows how shadow can be detected.

$$D_{SE} = Te_{SE} - Tb_{SE}.$$

The Amplitude max $Amax_{SE}$ in figure 1-3 refer to the maximum of the attenuation peak that can be reached, although represent Amplitude As_{SE} the average of the time window centered on the middle of the shadow.

The effects of shadowing caused by humans body lead us to consider that the channel unavailable during the shadowing process. I_{SE} is the difference between two Tb_{SE} of an single shadow event which happen one after the other.

1-2-3 Serial Shadow Event and Unavailable Ratio

The duration between several single shadow events can be very short or even caused by the same person walks across the LOS. But During a period of time several shadows can occur due to different numbers of people moving around crossing the through the link. Therefore we can define unavailable ratio that can express the

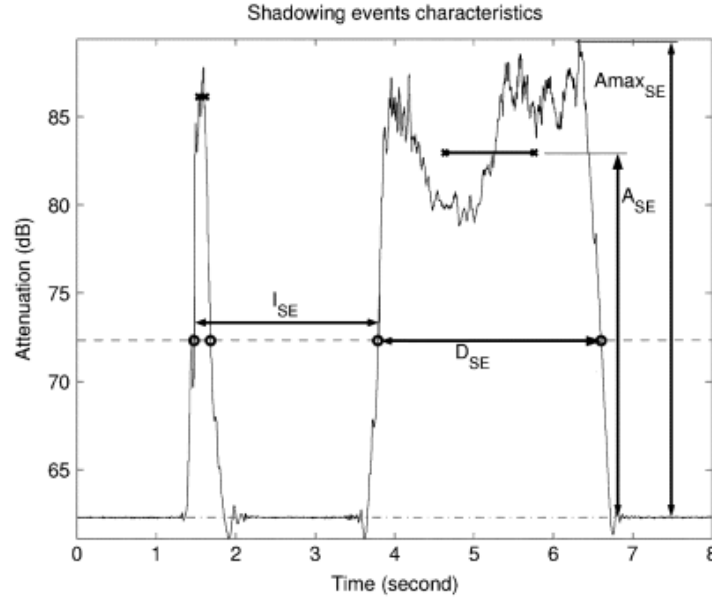


Figure 1-3: Shadow Characteristics

stability of the link, the unavailable ratio(R) is the sum of all single shadows events durations divided by the total time that required to have all these shadows events [2][10].

The unavailable ratio R for a channel having a variety of shadowing within certain time can be expressed as:

$$R = \frac{\sum_{n=1}^{N_{SE}} D_{SE,n}}{D_M}$$

- D_{SE} : The duration of a single shadow event.
- N_{SE} : Total numbers of the shadows have detected during a measured period of time
- D_M : Total measured period of time.

1-3 Our Goal And Related Work

The interest in using high data rate in wireless communications, as we have noticed, is gaining more attention and research specially large unlicensed available bandwidths around 60Ghz. From the propagations characteristics we can conclude that millimeters waves need direct path within indoor environments. For the indoor applications we found out also that shadowing made by human bodies, as result of their movements across the LOS, can significantly effect the receiver signal power level and make the channel unavailable, thus channel failure during shadowing.

It is very important to estimate the quality of the link and evaluate the channel availability from the networking point of view and protocol design. The previous model adopted in QoS routing protocols and ad hoc network improve mobile performance links, but the model has been generated according to results based on simulations or analytical equations. What we are trying to do in our project is to collect data, (shadows events), during long period of time using different scenario's inside natural indoor environments, such as students room, library, lunch room, or even students hall.

The availability of the link quality is one of the most important factor to influence the 60 GHz link quality, the quality of the link depends surly on the availability of the link, which can severely effected by human activity causing different singles shadows events. **Our goal is to study the effect or the influence of human's activities on the 60 GHz line of sight(LOS) communications in an indoor environment.**

In order to collect the data we need first to emulate the 60 Ghz directional antennas equipments using off-shelf directional transceivers , like optical or sound devices that can have similar shadow characteristics to the antenna's equipments and can be cheaper devices at the same time, quite available but the most important is that we are trying to have an insight on the blocking events therefore our emulation is for the movement's behavior rather than the characteristic of the 60 GHz Link. By creating the right emulator device we can start to examine en research the most suitable places to install the device en create a natural daily scenario. By collecting data from different scenarios measurements we can process our data to analyze the behaviour or the distribution of different criteria s like people arrival's time, shadow event duration, or even compute the unavailable ration during different time slots a day.

Influence of human activity on the propagations of the 60 Ghz Link took lately a lot of attentions of reseachers in order to estimate the path visibility for the real indoor scenario's [4]. Also there are plenty of measurements at 60Ghz for WLAN application in the past took place to determine fading statistics and investigate the impact of people movements effect on the temporal fading [13][12]. Polarization dependence of multipath propagation at high-speed transmission has been also investigated in turn of the direction of the arrival [9].

Link stability model for such service like Qos ad hoc routing algorithms have been, as we have mentioned before, well implemented in term of link survival time to assist ad-hoc routing protocol to improve the QoS performance[6], although that all based on simulations and static analytical equations.

Further more chapter 2 will explain the motivations and the reasons for emulating the 60 Ghz directional antenna equipments. The device choice can be made according to their functionality and the system boundary condition, in chapter 3 installing the chosen device(pair)and implementation o test the device. Chapter 4 determined the different measurements scenarios.Analyzing and processing the data in different intervals and fit the collected data will then follow in chapter 5. Chapter 5 will contain the conclusion.

Emulating 60 GHz LOS directional Antenna equipment And device choice

2-1 Motivations Aspects

Building an emulator device for any system need motivations research in different aspects and environment so that we can build a device that can meet the original(shadow) behaviour characteristics of the 60GHz shadow, therefore we will classify our evaluation into two types, physical, which based on 60Ghz shadow behaviour, and environmental, like installation's location, safety and system availability.

2-1-1 Shadow's Physical behavior concern

Emulating 60 GHz Link need first to research the shadow behaviour that is caused by human body crossing the 60 Ghz LOS. The shadow behaviour of figure 1-2 has three important characteristics from the communications point of view [3], namely:

- The fading rising time is very short compared to shadow events made by frequency signal.
- The duration time of the shadow is quite long, the effect of the shadow is still active as long as the shadow still blocks the channel.
- The fading Amplitude is quite clear.

These shortly explained characteristics have the key to lead us to find out a device that able to create a directional LOS, secondly we have to examine the shadow made

by human blocking the device's LOS what if his shadow behaviour or the characteristic has the similar influence on the emulated LOS with the 60 GHz LOS. Knowing the fact that The emulation process is more for the movement characterization rather than characterizing the 60GHz channel itself.

2-1-2 Environmental concerns

There are plenty of reasons made us think to emulate the antenna equipments, (Although some of them are reachable under high economical conditions while the others is just too far from getting implemented at the mean time), the reasons are listed as follow:

- (a) The high cost of the 60GHz Antenna equipments .
- (b) The availability of the equipments and a suitable working place.
- (c) The difficulty to displace the antennas in order to carry out the measurement scenarios at different places.
- (d) we want to have the first insight on the blocking events. The emulation is more for the movement characterization rather than Characterizing the 60GHz channel
- (e) Finding a fast and easy way to log realistic data.

we need the emulator device to give us the same performance as 60GHz link during the human body shadowing, and should be for sure available quite cheap devices, easy to implement and to update. Once again we don't need the emulator to give us the exact single shadow as the one observed by 60 GHz. But we need the emulator shadow behavior have a similar shadow characteristics of the 60 GHz like summarized in the previous section.

2-2 Device Choice

By researching the motivations aspects we can apply them on the devices that can meet the motivations conditions conceding different forms of electrical energy like optical, (laser,infrared), or audio like using sound card-microphone system with scaled voice packet frequency. From these three devices we will try to examine their functionality according to our motivations criteria in order to make the choice and build the device pair.

2-2-1 Available Devices

The three candidate devices that we first consider are:

- (a) The laser beamer device.(Optical device)
- (b) The infrared gate lock device.(Optical deice)
- (c) Soundcard-microphone system with scaled frequency voice packet.(Audio Device)

A ll three candidate have quite similar functionality regarding sending and receiving principle , in term of all devices need directional path between the transmitter and the receiver.

The laser beamer create a straight line from the transmitter to the receiver , once this direct path get blocked, then the link will be broken and no signal will reach the receiver. The infrared device functions exactly as the laser beamer dose except the fact that the infrared device regarding the small beam width of the infra red transmitter. The audio device contain an sound card system create and send voices-signals at 68 kHz. The soundcard-mic system can emulate the 60GHz radio signal by downing scale the high radio frequency to lower frequency at 68KHz. The scalling goes as follow :

Miliemeters waves have a speed of $3 * 10^8 \text{ m/s}$, the speed of the sound is 343 meters per second

$$\text{The scaled voice packet frequency} = \frac{60\text{GHz} * 343 \text{ m/s}}{3 * 10^8 \text{ m/s}} = 68.6 \text{ kHz}$$

The sound card, connected to the PC or laptop, sends packet thought the PC speakers(transmitter) to the special microphone that can receive the voice and save,process, the voice packet using the same PC. If the path between the transmitter (speakers)and the microphone(receiver)get blocked, by human body for example, the packets will not make it to the microphone, although the microphone will need a few Millie second delay to report the missing packets.

Finally the three devices will get tested according to the Motivations aspects to find out the most suitable device that can help us to emulate the 60 Ghz LOS.

2-2-2 Devices Comparsion

The three devices will parallely get evaluated according to the two types of the motivations aspects.

Shadow Physical behavior

Parallely we will test our devices according to the physical behavior of the shadow, of subsection 2-1-1, that can caused due to human activity:

Table 2-1: Devices Shadow Physical behavior

Shadow Physical Behavior		
(laser device(Optical))	Infrared gate lock device (Optical)	(Sound card-microphone system (Audio))
Short fading time	Short fading time	Quite short fading time, delay depended
long Shadow duration time	Has a long time duration	shadow duration is time delay dependent
Clear amplitude	Clear amplitude	Clear amplitude , time delay depended

The Shadow behaviour of the three devices show some similarity with the behaviour of the shadow that we have seen on the previous part 2-1-1. Although that the sound card shows time dependency by raising from the cut-off(shadow) situation to channel available and vice versa. Further the two optical devices have shadow behaviour similar to our original shadow of figure1-2.

The optical devices have a better shadow behaviour comparing to the short time delay by the Audio device, nevertheless we can make now no decision at this stage till we finish our entire test.

Comparison on Environmental concern

We can also test our three devices according to our environmental concerns, The following table list our three devices environmental concerns:

Table 2-2: Devices Environmental concerns

Devices Environmen- tal Criteria	The laser Beamer de- vice(Optical)	The Infrared gate lock device(Optical)	Sound card-microphone system(Audio)
Device Availability and Equipments costs	Inexpensive equip- ments,Available to build ,and system upgradeable	Inexpensive equip- ments,Available to build ,and system upgradeable	quite expensive compared to the optical equipments, specific equipments order , limited availability.
Device Mobility and local displacement	Easy to mobile and to locate in different places	Easy to mobile and to locate in different places	The sound card is hard to locate and quite sensitive equipments, uneasy to re- place under any damage circumstances
Natural side effect influences(noise, hu- man body)	Possibility of risk , laser can harm hu- mans eye	100 Risk free device	100 Risk free device.
Data logging and Data storage	Does n't need huge capacity for data storage	Does n't need huge capacity for data storage	The system needs huge amount of capacity to store the logged data

2-3 The result of the Device Choice

Based on the comparisons, we can conclude that *the Infrared gate lock device is the most suitable device to emulate the 60 Ghz link Antenna equipment*. The fact that the laser can have a side effect on people during measurements, (irritate human's eye), made us take no risk with the device and chose the infrared instead. Comparing to the audio system it is quite obvious that logging data with the infrared device is much easier and ask much less store capacity than the audio system, so as matter of efficiency the infrared device has better performance. The availability of the device and update possibilities made the choice look also not hard.

Chapter 3

The Infrared Emulator Device

Before we start implementing the infrared device it might be useful to remind ourselves the goal of implementing such a device. We are trying to study the effect or the influence of human's activities on the 60 GHz line of sight(LOS) communications in an indoor environment by field measurements. Field measurements means that we have to loge(collect) data, the duration of a single Shadow Events created by human activity(body), in different time slot a day by different natural indoor scenario's. we have chosen the optical infrared device as our emulator to emulate our original link according to the given concerns in the previous chapter.

Implementing the Infrared device in order to loge data, need data storage capacity, and the device has no capability to loge the data itself. Therefore we need to implement an extra system that can interface with the hardware component in the infrared device in order to save the data.The most suitable option indeed is using a personal computer to loge the data via a hardware-software interface program that is able to communicate with infrared device through one or two control signals.

The infrared emulator device consist of, therefore, as follow:

- (a) Hardware component consist of a sender and a receiver terminal to create the directional LOS.
- (b) Hardware-software interface device who can covert the analog control signals coming from the receiver to digital control signals.
- (c) Software program that can use the digital control signals in order to loge data and compute the duration time of an single shadow event.

3-1 The Hardware Componets

The hardware components is a ready infrared light barrier kit consist of transmitter and receiver terminal. During our measurements we have been using two different kits, one with 5 meter LOS distance(max)3-1(a) and the other with 18 meter distance LOS(max)3-1(b). The functionality and the principle is exactly the same both create a directional line of sight between the transmitter and the receiver, once a human body or even a part of human body for example(arms,legs), comes between the signal will be blocked and the receiver acknowledges the signal missing by controlling a visible red (LED) alert.

The red LED alert goes on when the connection between transmitter and receiver get blocked, or shadowed. The red LED have been used as the analog control signal namely, when we know exactly when the light goes on and for how long then we know enough about the created shadow already, like the incident time for the shadow and the duration time of a single shadow. The both hardware kits looks as follow:

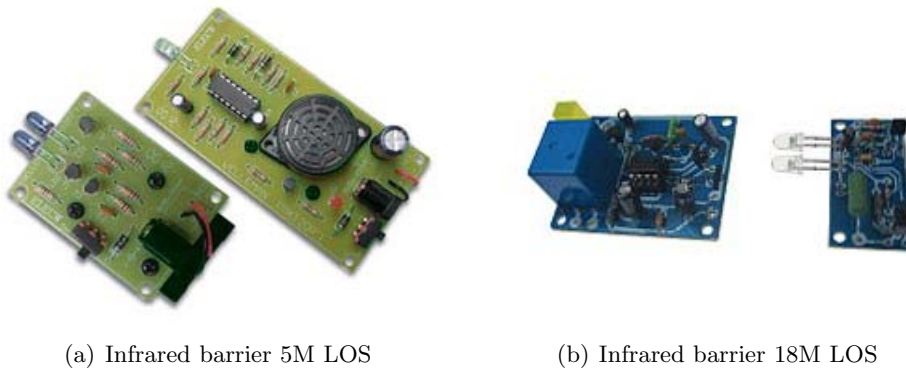


Figure 3-1: Infrared Devices

The default voltage value across the LED when shadow accrues is equal to 1.4 volt(in case of 5m gate lock) en almost 2.35 volt by the other (18m,which means that the signal level start with zero volt in case of clear LOS and jump up to the default value. In this case we get a sort of block signal when a single shadow events happens. The Next two figures we compare the two shadows made by human body within 2 different equipments namely the 60Ghz antenna equipment and the infrared gate lock device. The shadow form can quite different from one to the other but the principle of computing the duration time can be quite similar although that the shadow made by infrared may look a few milliseconds bigger than the one detected by 60 Ghz antenna equipment.

Data sheets including the transmitters and the receivers specific electronic's map have been attached in appendix A1 for further extra information regarding the kits functionality and the subcomponents specifications.

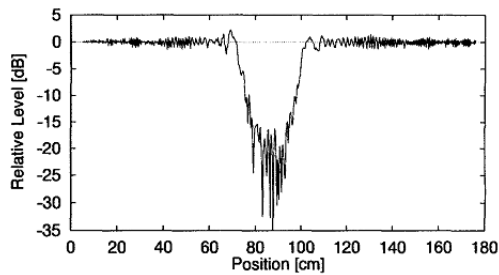


Figure 3-2: Single Shadow Event by human at 60Ghz band

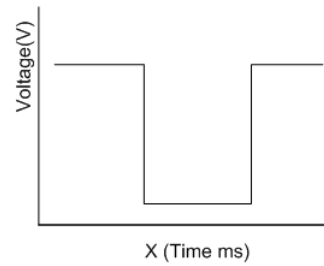


Figure 3-3: Human Single Shadow Event detected by infrared gate lock device

3-2 Hardware-software interface

The hardware-software component is a data card reader from national instrument model 6008. The card has a 32ports total 16 analog port input and other 16 are digital output ports. The data card is synchronized with different kind of software, although national instrument made the card to work with Labview software program. the card is easy to install via an usb cable to a PC or Laptop. Appendix A2 have more detail over the data sheet and possible installation tips.

3-3 Software implementation

The software part usually is the complex part, we need to chose an compatible software program in order to log data into the hard disk but also try to read the data from the infrared device via the data card, which means that the data card should be identified by the software in a way that both should communicate. The software that we have been using is Labview 8.5, which is a sort graphic programing create an electrical counter that start to count at the moment the signal at the receiver disappear, or when the red LED goes on.

At this moment the software program try to save the incident falling time when the signal is gone (cut-off), at the very same time it starts counting till the signal level become zero again and the receiver give no alert anymore for blocking path (carry on). The final result of the program is 2 columns with fall and raising time saved in note pad file form.

The fact that the software saves only the incident falling and the raising time is that we are only interested, as we have declared before, on the movements and the activity of human during the measurements that blocks the LOS and caused a shadow, beside saving the fall and the raise time will save too much capacity in our hard disk, specially when u know that the time duration of an shadow is nothing but the different between the falling's and the raising's time. Beside the fact that when u load your software less instruction, you will reduce the time delay of the implementation in general, therefore we reduce the error of an shadow time duration

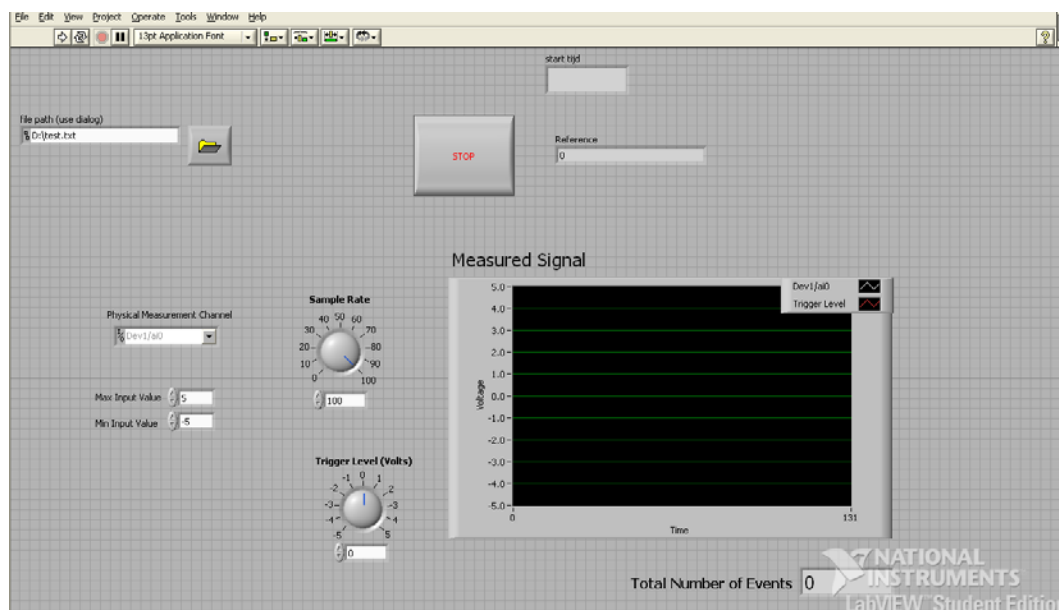


Figure 3-4: Lapview window for Infrared Counter

even if it's a small percentage. Programing in labview is graphic. By selecting the right software components and connect them to each other, a software circuits can be built under the given control signal that is received from the data card. Once a human block the path the receiver sens it and sets a voltage drop on the LED which in turn is connected to the data card which feels the change in the voltage drop and send the digital signal to the software which considers this signal as the start button to save the incident fall time. If the the path becomes clear again the receiver set the voltage on the LED again to zero and the signal level going to the software become zero too, which is the sign to stop counting and save the raising time. Data can be logged and saved to notepad file containing the fall-raise time, date and the time of the measurements session. Further contain the result file also reference number which is essentially very important during data processing en fall time computations. Figure 3-4 shows how the program window looks like on the PC screen, u can simply click the buttons that u can see in the screen widows, like stop bottom or even the start one, under the edit option, further there are buttons to create a notepad file in order to save the result file in a certain directory. the black screen is when we can see the signal level if the signal level zero then there is no shadow become almost -1.4(5 meter device) or even if -1.9 in the (18 meter device) then we know from the signal level that there is a shadow occurs.

Figure 3-5 shows how the graphic software program looks like behind the window figure that we have seen before.

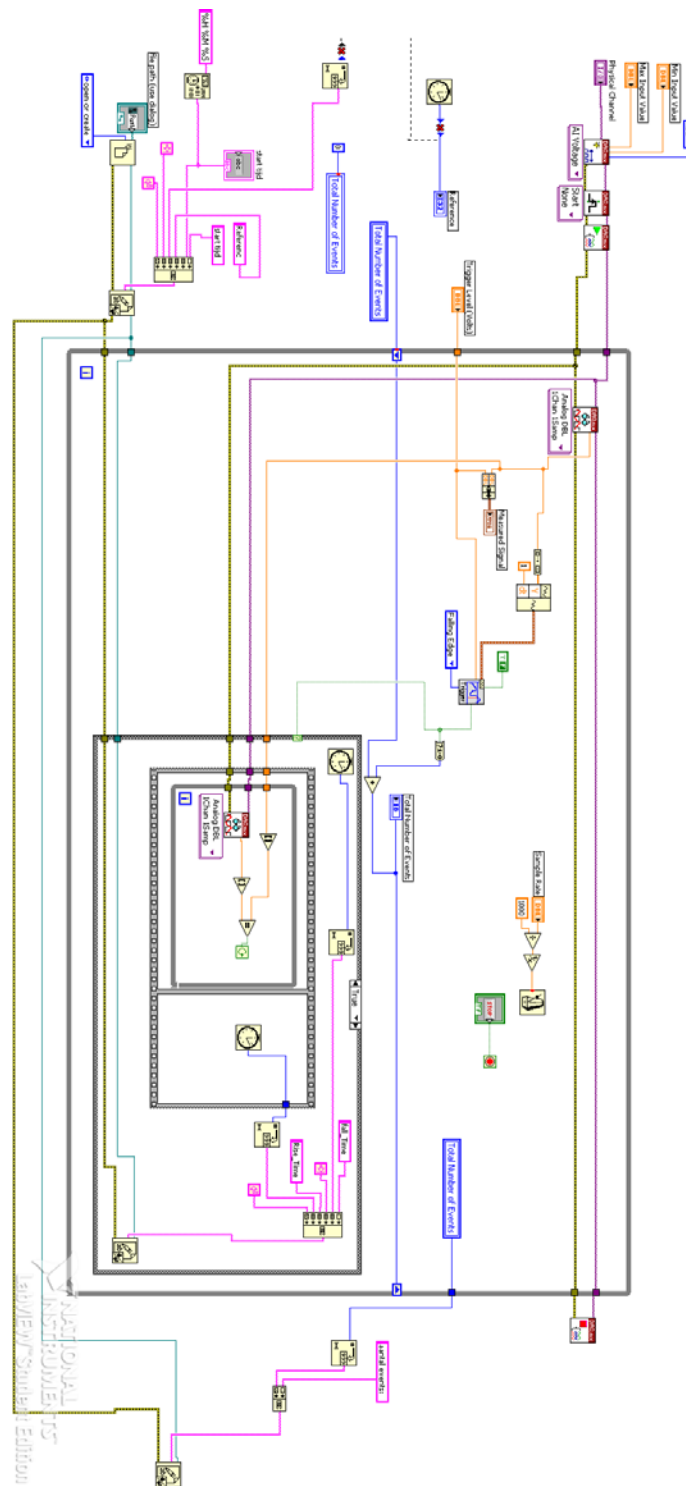


Figure 3-5: Lapview Infrared Counter Program

Different Measurements Scenarios

The infrared emulator have been tested after implementation under different conditions in order to test the functionality as one hole system. The next stage of our project is to start measurements under different natural scenario. Natural scenarios means that we have to look for an indoor environments where human activity is taking place and locate our emulator inside the place without leading to effect the way that human activity was before. For example, never use big equipments that can block a normal path people use to walk through before, or never place or locate the emulator in a way make people pay extra attention and let them do unexpected or non spontaneous movements which could effect our measurements, in term of making extra shadows or even less, because of the fact that people temporary start to walk the other way around.

Therefore our measurements scenario should be as much as natural as possible and the installation of the emulator should not block any given natural path or let people pay more attention regarding the emulator public location.

During the measurements we tried to compress the error as much as possible and tried to solve the problems in order to reduce the given error. But that will never change the fact that by any measurement there are always errors involved. Errors can take different forms like, technical error, functional or even human influence can deliver unexpected errors. Technical error can take place during measurements like laptop freezing while the program running costing a few seconds to run the program again while people moving their natural way, thus one or more shadow have been missing.

From the other hand if the battery of the transmitter or of the receiver run out, then we have signal that can be translated as a shadow while no body walks through, also replacing the battery can take a few seconds while we have shadow have been logged.

Finally human's influences can also create unwanted errors in case of somebody obey his curiosity and stand in front of the device trying to figure out why this device right here in this room. We can't blame him as electrical student trying to find some answers, but then we have extra long shadow that express no natural movement.

4-1 Trial Measurement

Before looking for the right indoor location to plan our scenario, we decide to do some measurements for three different location, the Central Exit gate for the EWI Building, the Central exit gate for the Dribbleweg Practical building and the stair hall first-floor EWI building leading to the restaurant.

The reason behind trial measurements that we tried first to measure people's shadow in different location at different time slots of the day and from that we might can see if there are any similarity in people's movement, namely trying to do the same effort leaving or entering a building, Also it is interesting to do that with different height of the transmitter and the receiver terminal from the ground, for example we start to measure the Main Exit gate of the EWI building at 45cm and 100cm height from the ground, it is interesting what the shadow behavior can be having the LOS once down your knees once and up to your waist the other time, it is challenging to know the answer specially when u know the fact that your are changing the thickness part of your body who is basically causing the shadow.

One more important point is that people arrival time, in spite the location's different at the three places we still dealing with people who are leaving or entering the building, restaurant, on different time slots a day. Thus plotting a simple CDF curve from the collected data will give us, may be, an idea about how the people's arrival time look like, or is there any similarity of movements around a given time slot. These information are quite important for us in order to think about a real natural location to carry out our measurements in order to collect the right data that WE CAN BASE OUR CONCLUSION ON.

4-2 The Indoor Scenario

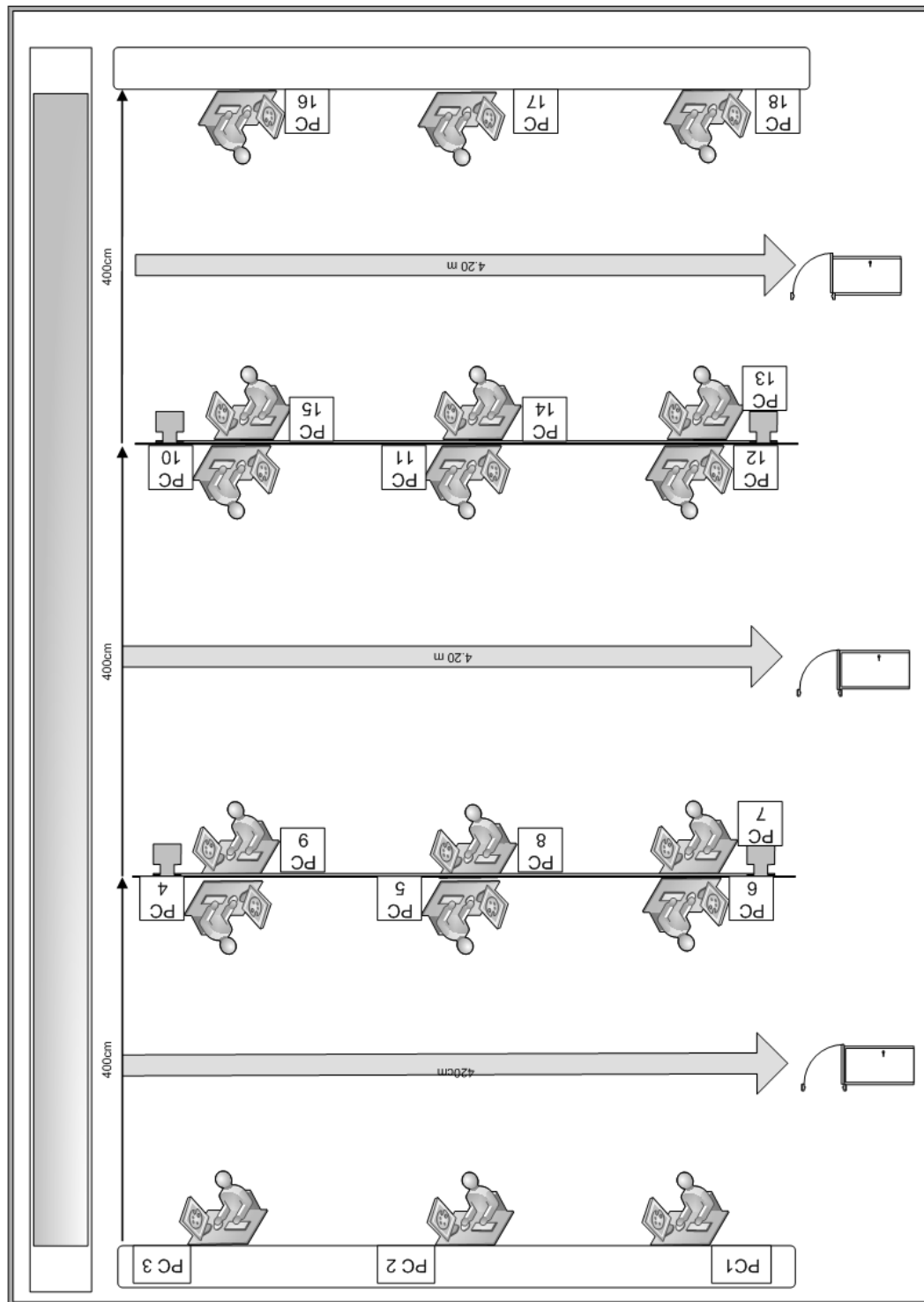
4-2-1 The Indoor Location Choice

Based on the observations results from the previous measurements, we need to consider the right location to install and displace the transmitter receiver kit. Once again natural human activities required, like 19th floor student's room, or even employ's office also at the 19th floor, therefor we decide to chose the student't room to do our measurements on for the following reasons:

- (a) The room's capacity is quite big to do measurements, and locate the devices in the right location.
- (b) The traffic of human's activity in the room. There are at lest 6 up to 7 students who are working under regular bases, the regular bases have been set according to the student's average working days on his own thesis. The rest of student are under average of 2-3 days a week.
- (c) The distribution of the students around the room can create a traffic in both direction if we could usethe right scenario, knowing the fact that students are distributed symmetrically around the room.
- (d) A real natural scenario movements, with big chance of traffic than an employ's room.

Figure 4-1 illustrates how the students room usually looks like. The room size is quite 12 by 5 meters, further arranged into 3 halls each hall has 6 desks with 6 separate PC for each student to work on individually. Looking at the situation from telecommunications point of view, if we are considering 60 GHz connection being established between the PC's, there are plenty of possibilities where the students PCs can be connected with each other, or connected to an access point hanging right on the wall or at the ceiling. The combination of connection is so many but we decide to measure only the links that can have the most influence from the students movements.

Figure 4-1: Students Room At the 19th Floor EWI Building



4-2-2 The students Room Scenario

The scenario measurements in the student room will take two phases:

Phase One: We use one pair infrared device(5m distance between transmitter-receiver)to measure the students activity on the following single links of figure 4-1

$$PC1 \longleftrightarrow PC6, PC7 \longleftrightarrow PC12, PC13 \longleftrightarrow PC18$$

Figure 4-2 shows the different single links scenarios.

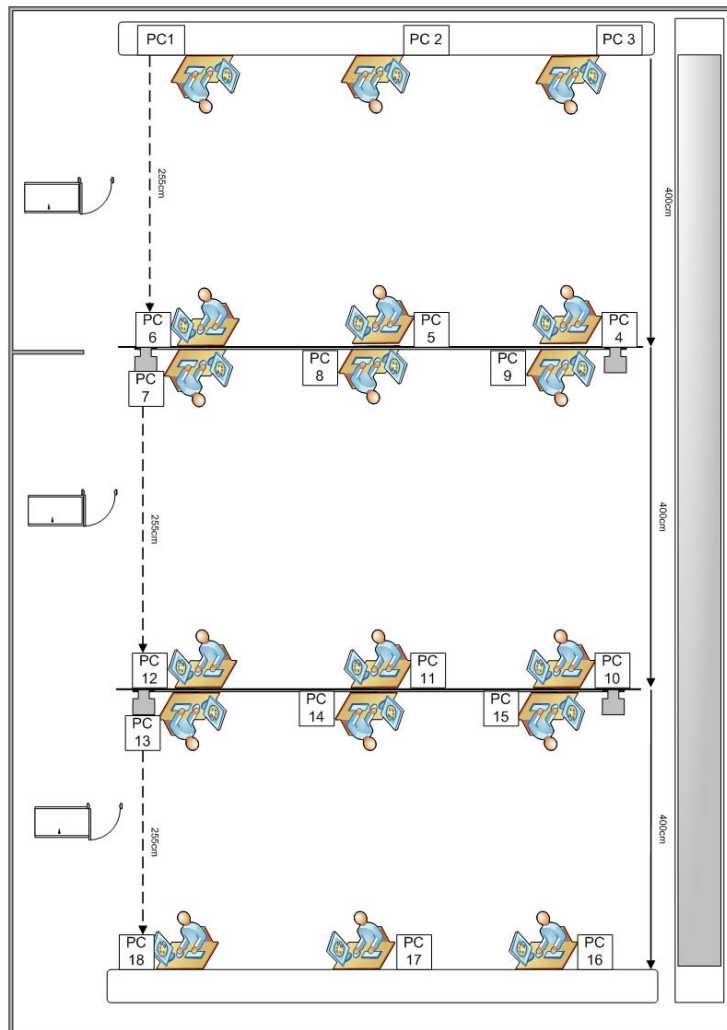


Figure 4-2: Single Links Of the Student Rooms 19th Floor EWI Building

Phase Two:

We use two pairs of infrared devices to (5m,18m) to measure the students activities from single link $PC7 \iff PC12$, and a single link from an access point have been hanged on the wall(Infrared sender of 5m range about 200 cm height from the ground)next to the second door about 2.50 meter distance from PC12.

Figure 4-3 shows the access point hanged on the wall of the second door at the Students room 19th floor EWI building.

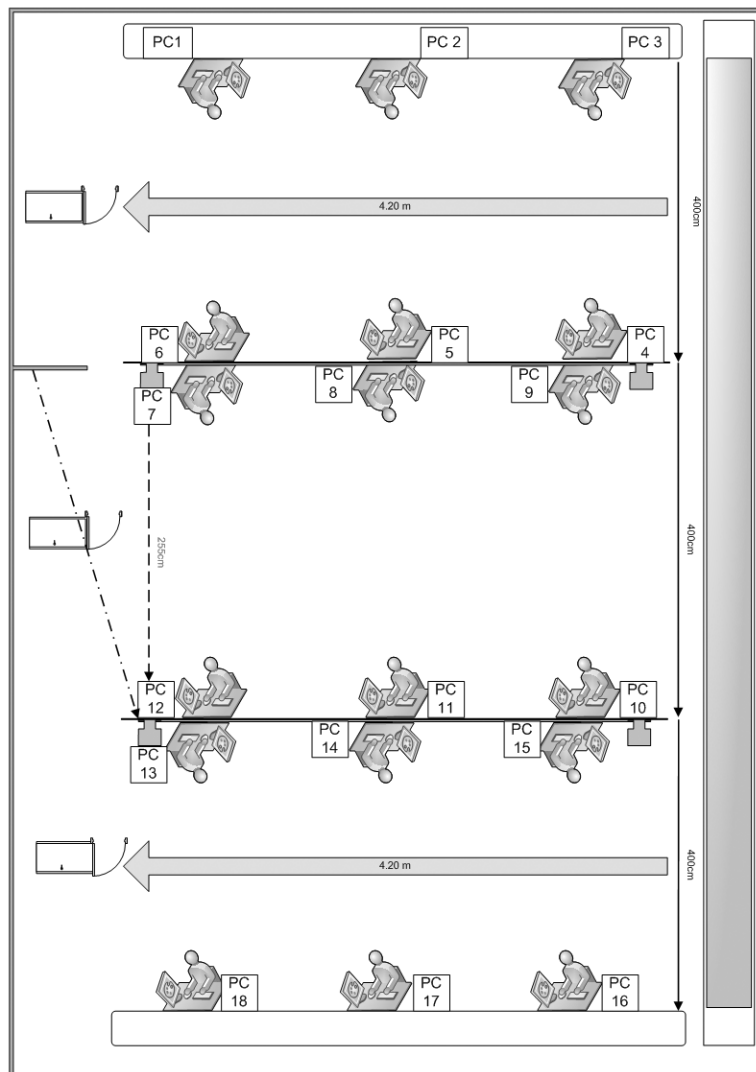


Figure 4-3: Access Point scenario Of the Student Rooms 19th Floor EWI Building

Phase one is measurements to express the activity of the students in every hall, the reason we try to measure all the three halls is that we deal with different size, behavior and walking speed of the students and we expect different movement's behavior from each student. In spite all that we are also looking for the possibility of any similarity in movements pattern regarding the three halls. The second phase measurements is extremely important to examine the different probabilities.

Figure 4-3 shows us there are plenty of chances that the wall link get broken and the other not ($PC7 \iff PC12$), or vice versa, there is also a chance that a coming person from hall one walk straight to hall three without crossing inside hall 2. The same situation can happen if one person leave hall 3 from door number 2. Possibilities can go on but all what we have to do is gather the data at different time slots a day or even a whole long session from the day and try to plot different unavailable ratios in different time slots.

Further we checked in our measurements that the desk's height in the student rooms are all the same namely 87cm and the distance between two single link is uniformly classified in the three halls of the entire room and equal to 2.55cm. The height of the access point is about 290cm on the wall almost as much as normal height of an WLAN access point. The first phase scenario have been implemented first and then the second phase measurements started after plenty of session have done on the first phase. The number of session and the time duration of every session will be clearly explained in our next chapter when we try to analysis our captured shadow event data.

Finally the errors that we properly will face during this scenario is just the traditional errors that we have mentioned at the very beginning of the chapter.

Measurements Scenarios Results, Analysis

The different measurements scenarios that we have planned at the previous chapter made us collect different kind of data sets. The data have been collected in different time slots of the day and saved for later process. Once we finish one phase from our scenario we start to process our data and analyze it. We planned two kind of measurements, trial and indoor measurements scenario. The Math Works software language, MATLAB, supports the entire data analysis process, from acquiring data from external devices and databases, through preprocessing, visualization, and numerical analysis, to producing presentation-quality output. Therefore we have been using Matlab to process our data and analyze it and or presenting different data plots. Another kind of software we have been using during our data processing is EasyFit, allows to automatically or manually fit a large number of distributions to our data and select the best model as enabling us to solve a wide range of problems with knowledge of statistics.

In this chapter we will present our result in different processing steps or phases that makes the compare between all scenarios easy to follow. The processing phases are as follow:

- (a) Processing the collected data, classified it in uniform time slots, compute and plot the Unavailable ratio(R) in different time slots of the day, for example if we have a measurements session of 20 min then we classify that to 4 slots of 5 mints and compute the unavailable ration every 5 min. We do that for the two scenarios namely the trial and the indoor measurements.

- (b) we process our data to compute the Single Shadow duration for every event in each data. Further we compute the people's arrival time in each data, an arrival time interval is a time(ms) difference between two starting's points of two shadows in a row. Later we plot the empirical CDF for both above two cases but then for both measurements scenarios data. Maximum, minimum, and the mean of the shadow or of the arrival time will be also computed.
- (c) We use Easyfit software to have a wide range distributions fits for the all logged data of the two devices Indoor Measurements Scenario. Further we can evaluate the most suitable model that Easyfit have chosen for our data.
- (d) Using a software like Easy fit is easy and effective but then we have to check how similar his distribution model's parameters that he had found out compare to a very frequent model estimator like the Maximum Likelihood Estimator(MLE). MLE can be implement and run by Matlab. Also we do that only for the indoor measurements data.
- (e) Finally we try to customize a mathematical distribution model to suit our indoor measurements data using MLE. Then we evaluate this model and compute the parameters difference between the customize distribution model and Weibull or exponential established distribution model, found via the software in phase C.

5-1 Phase A

As we have mentioned before we collected the data according to the two different scenarios, trial and indoor measurements. The trial collected data consist of four or five session of 30 mints maximum, for three different places. The main entrance of the EWI Building Mekelweg 4, the main entrance Lab building of the Drebbelweg 5, and the EWI Restaurant Entrance coming expecting people from the stairs or the lifts in both direction.

The indoor Measurements contain session of circa 5 a 6 hours total time period.

5-1-1 Trial Measurements Result Phase A

We measured the EWI building in two different ways, namely with 47cm transmitter-sender height from the ground, and with 100cm height from the ground for both transmitter-sender. we did that in four session of circa 30 mints. Further we went to

measure the electrical Lab building main entrance also we did their four measurements of circa 30 min knowing the height of the device transmitter-sender was 100 cm. Finally we measured the EWI Main Entrance three times of 30 min each. We divided the total time for each session to equal time slots of 5 min and computed the unavailable ration for each time slot. The results for the EWI building at 47cm transmitter-sender height look as follow:

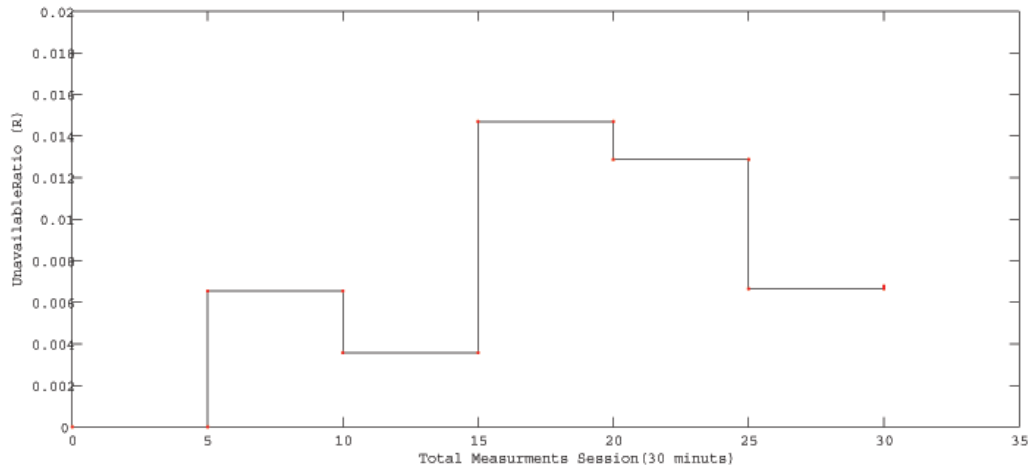


Figure 5-1: EWI Building Entrance:Session1 start time 14:25:31

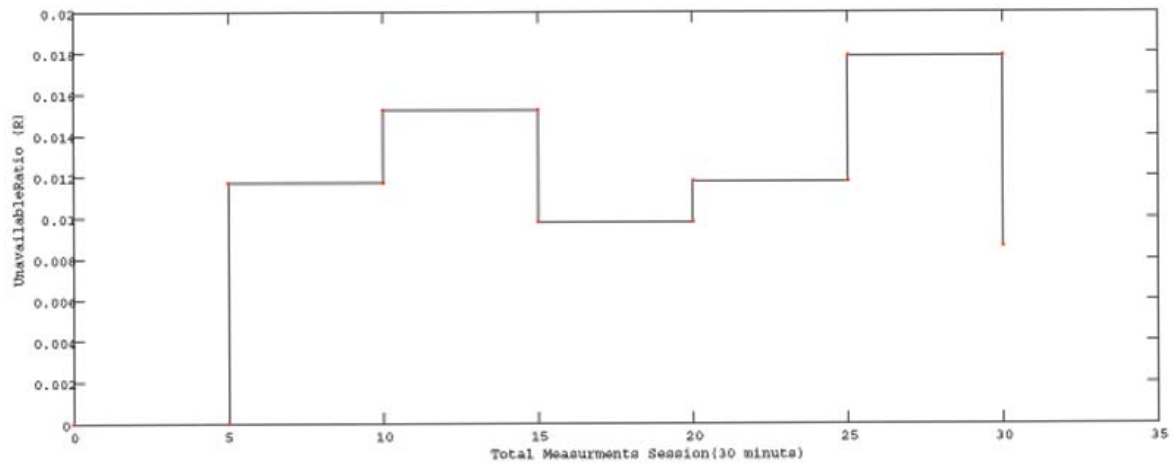


Figure 5-2: EWI Building Entrance:Session2 start time 15:07:28

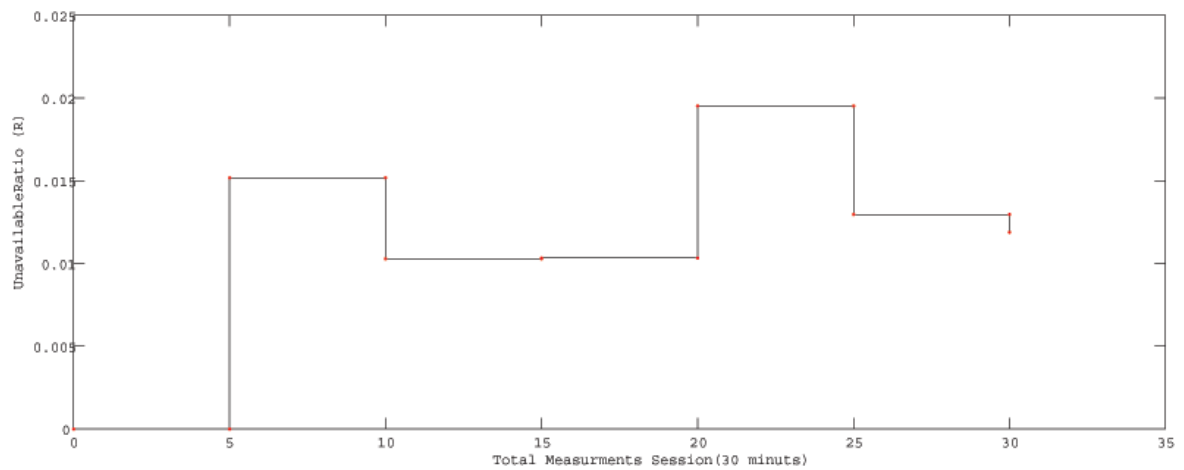


Figure 5-3: EWI Building Entrance:Session3 start time 15:44:06

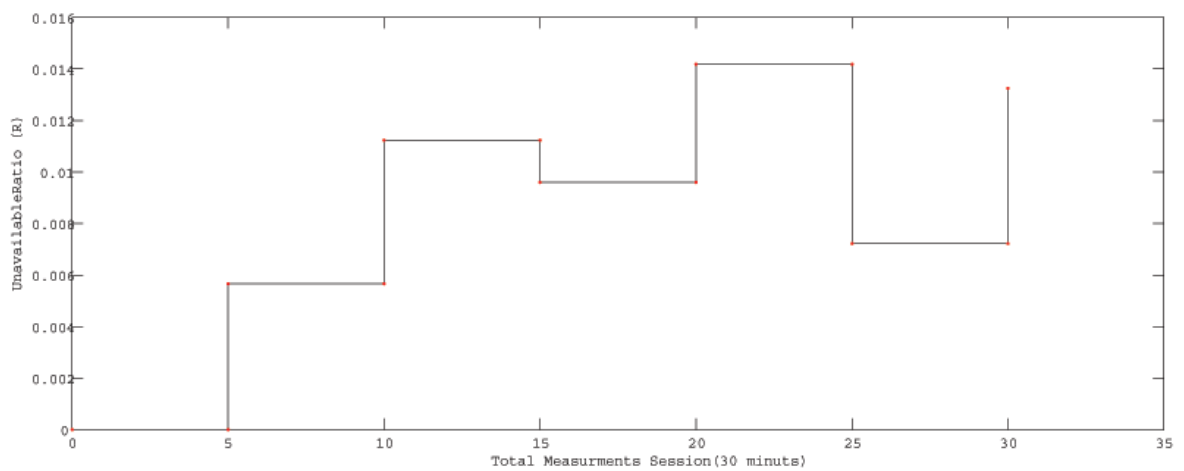


Figure 5-4: EWI Building Entrance:Session4 start time 16:17:05

The results for the EWI building at 100cm transmitter-sender height look as follow:

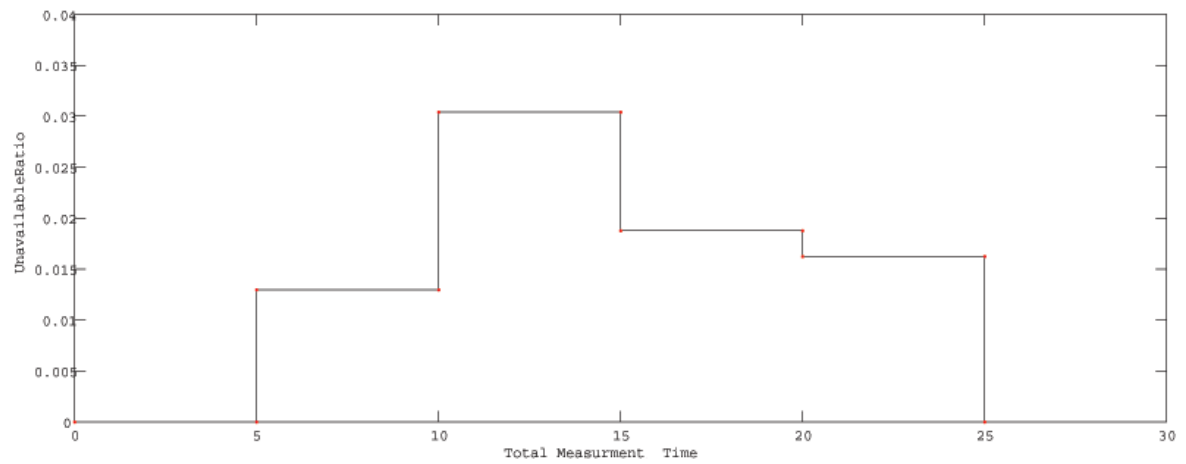


Figure 5-5: EWI Building Entrance:Session1 start time 15:53:31

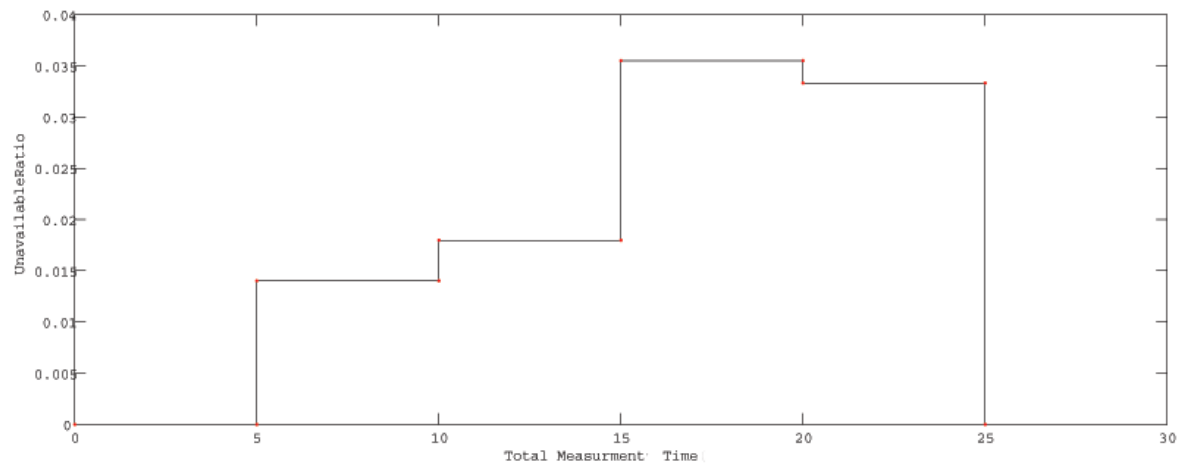


Figure 5-6: EWI Building Entrance:Session2 start time 16:17:28

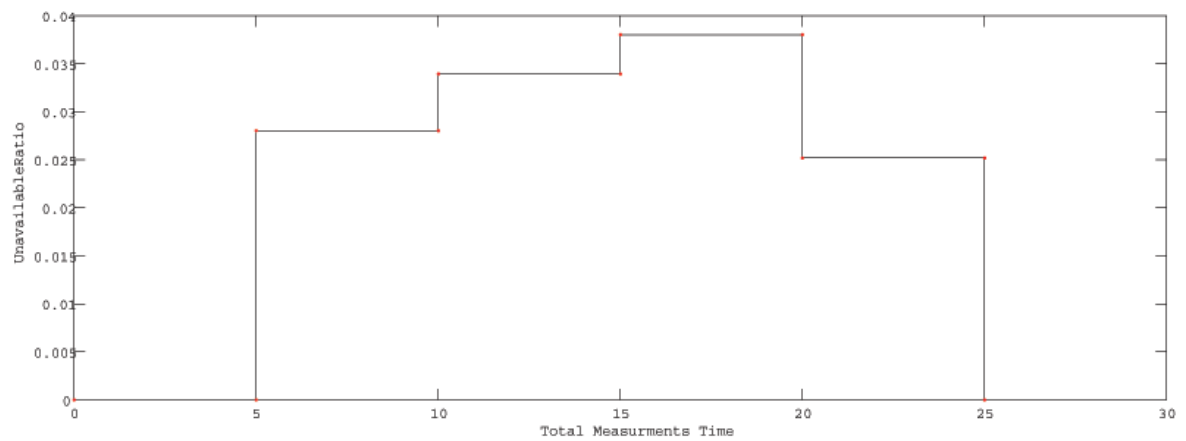


Figure 5-7: EWI Building Entrance:Session3 start time 15:44:06

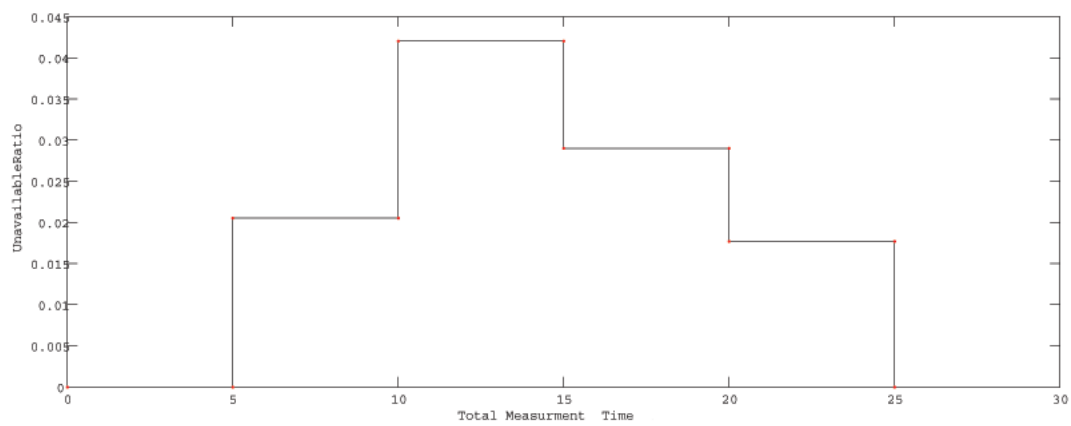


Figure 5-8: EWI Building Entrance:Session4 start time 16:59:05

now we consider the Practical building at 100cm transmitter-sender height, the measurements result are as follow:

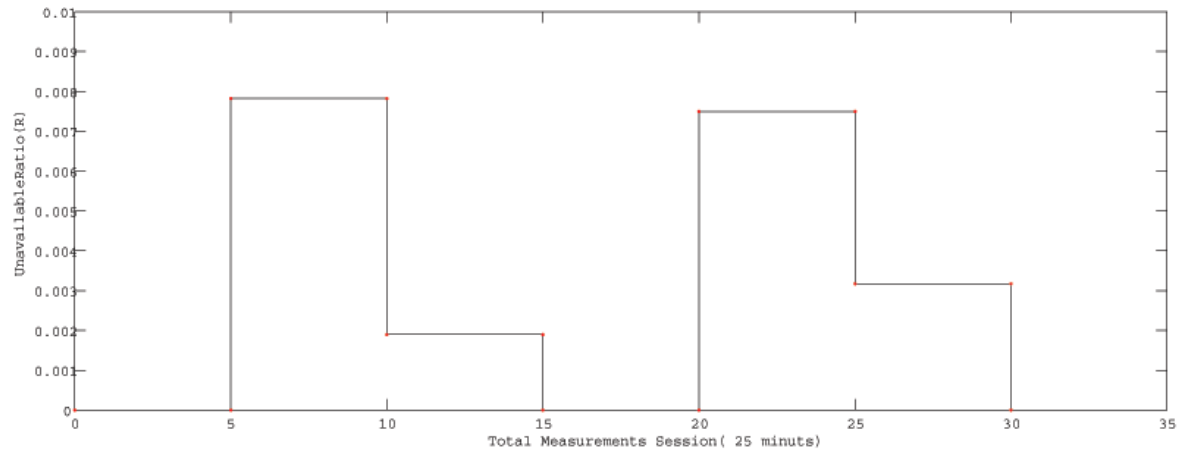


Figure 5-9: EWI Lab Building Entrance:Session1 start time 14:43:31

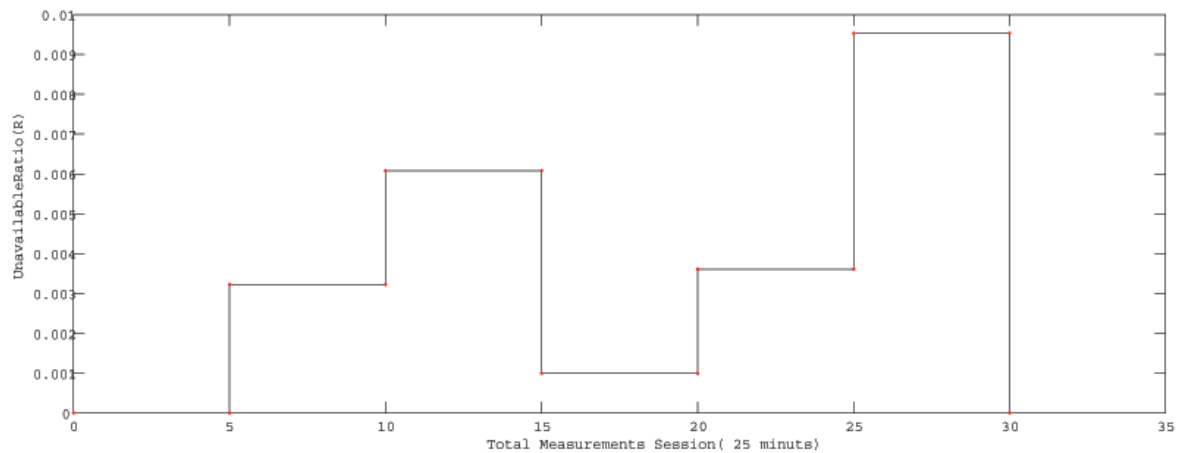


Figure 5-10: EWI Lab Building Entrance:Session2 start time 15:39:28

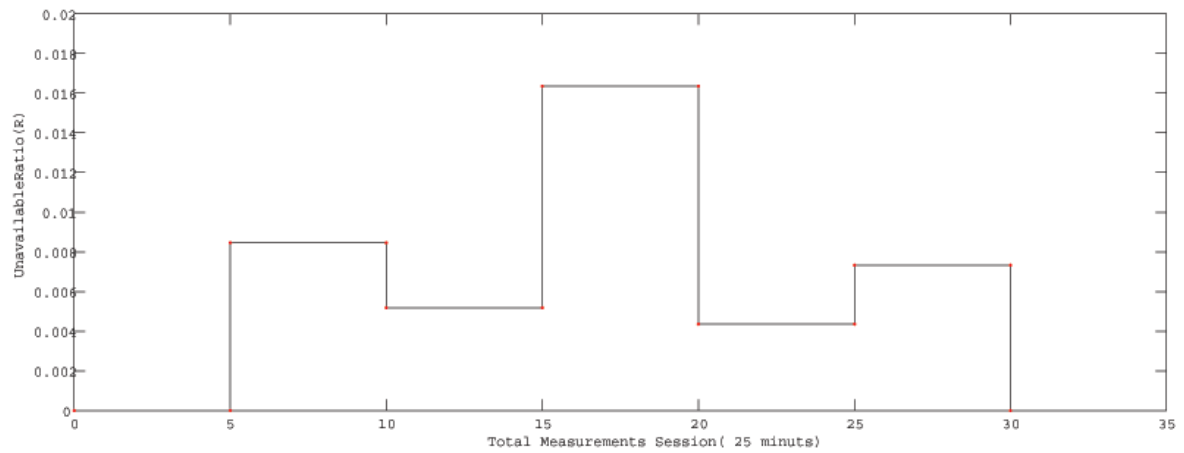


Figure 5-11: EWI Lab Building Entrance:Session3 start time 15:18:06

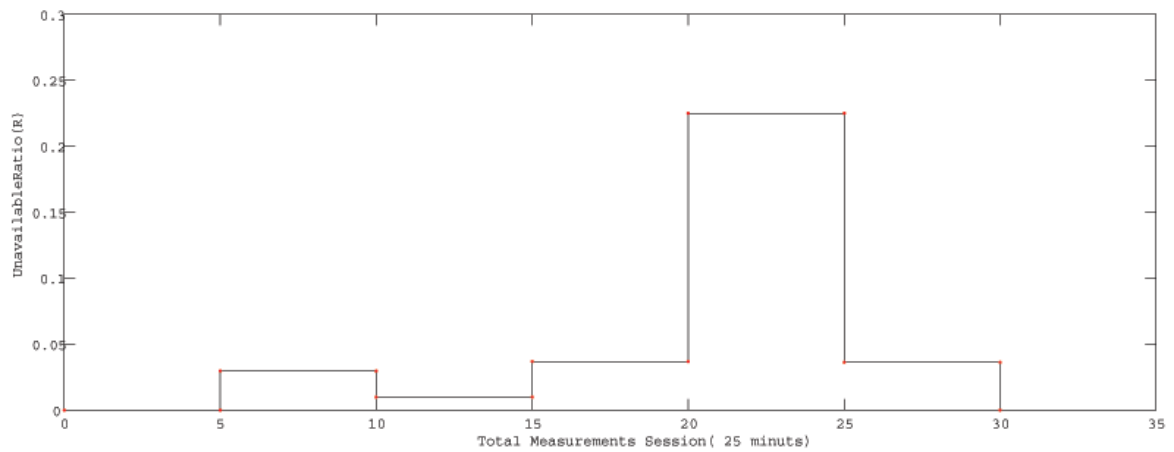


Figure 5-12: EWI Lab Building Entrance:Session4 start time 16:50:05

Finally the result for the EWI Restaurant main entrance look as follow

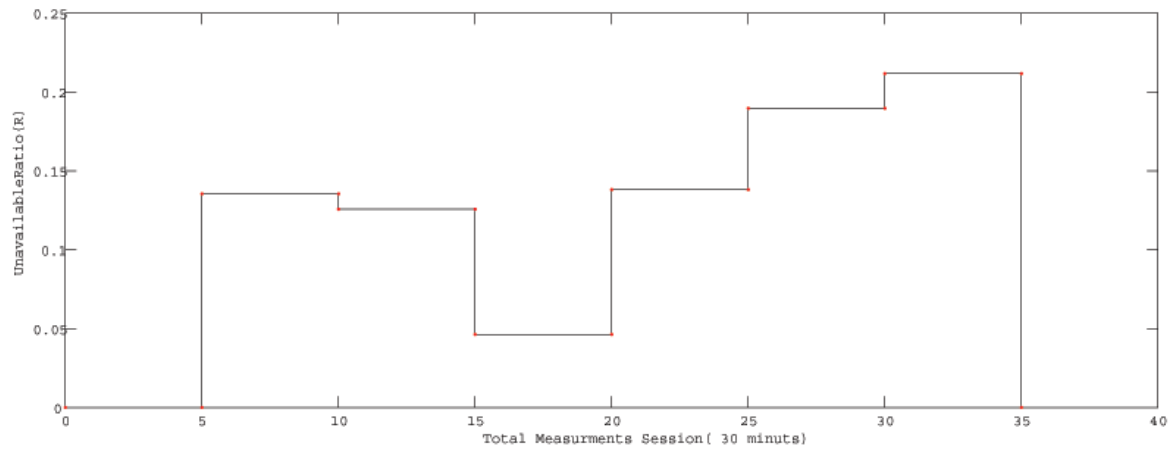


Figure 5-13: EWI Restaurant's Entrance:Session1 start time 11:23:31

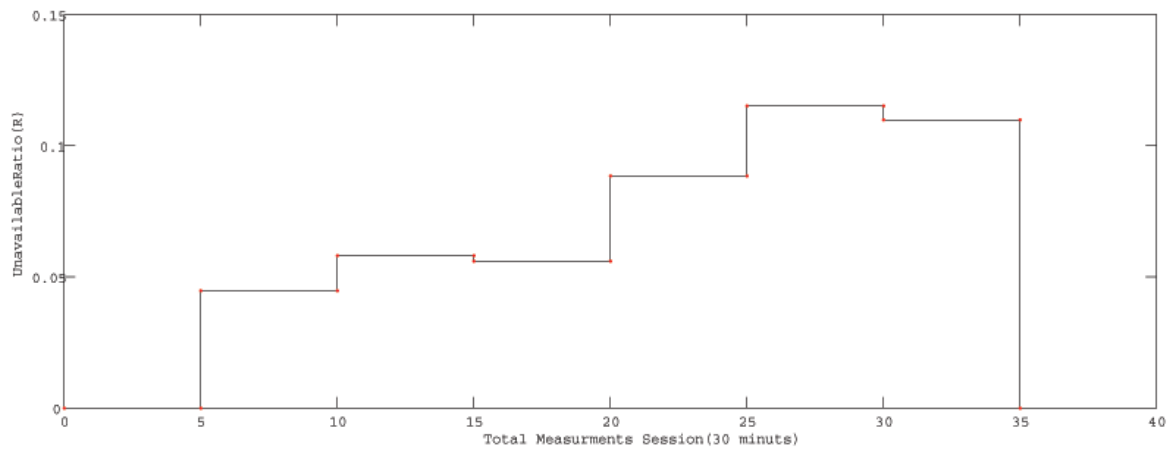


Figure 5-14: EWI Restaurant's Entrance:Session2 start time 12:01:28

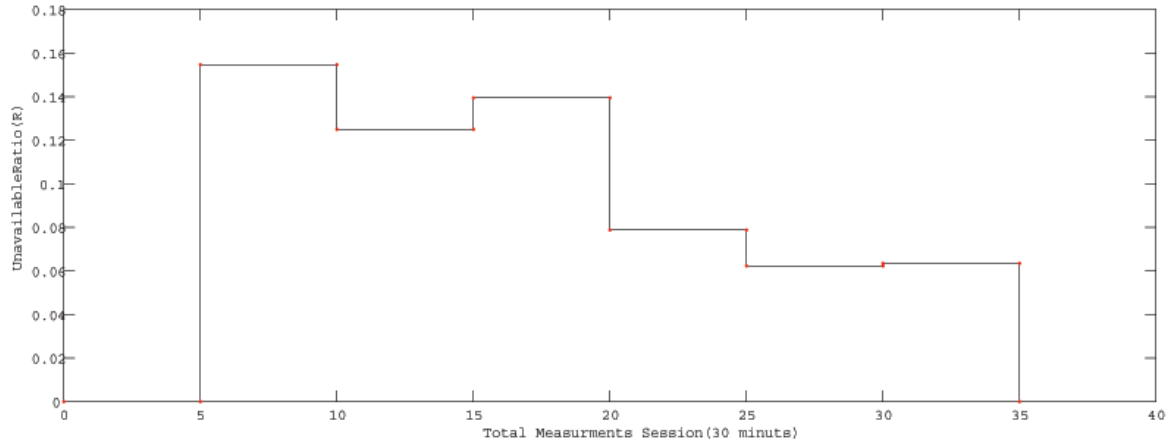


Figure 5-15: EWI Restaurant's Entrance:Session3 start time 12:40:06

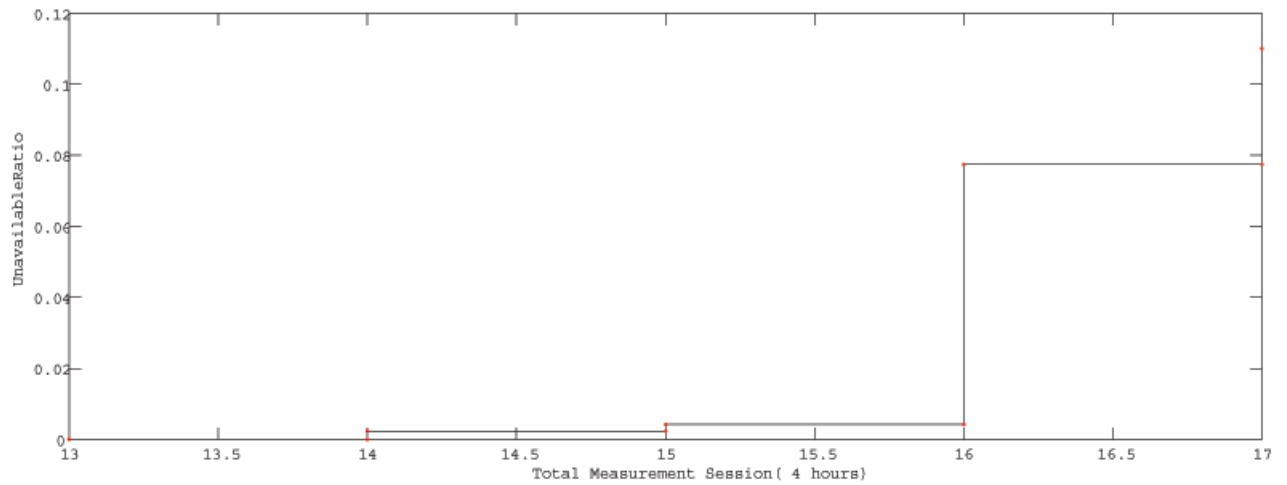
The unavailable ration have been computed according to the formula we have introduced in chapter 1 but then with total time of 5 mints, because we are computing the ratio R every 5 mints for example figure 5-13 the ration of the first 5 mints,(0 to 5), is equal to 0.135 and he second ration by 10 mints is 0.125 and so on.

5-1-2 Indoor Measurements Result Phase A

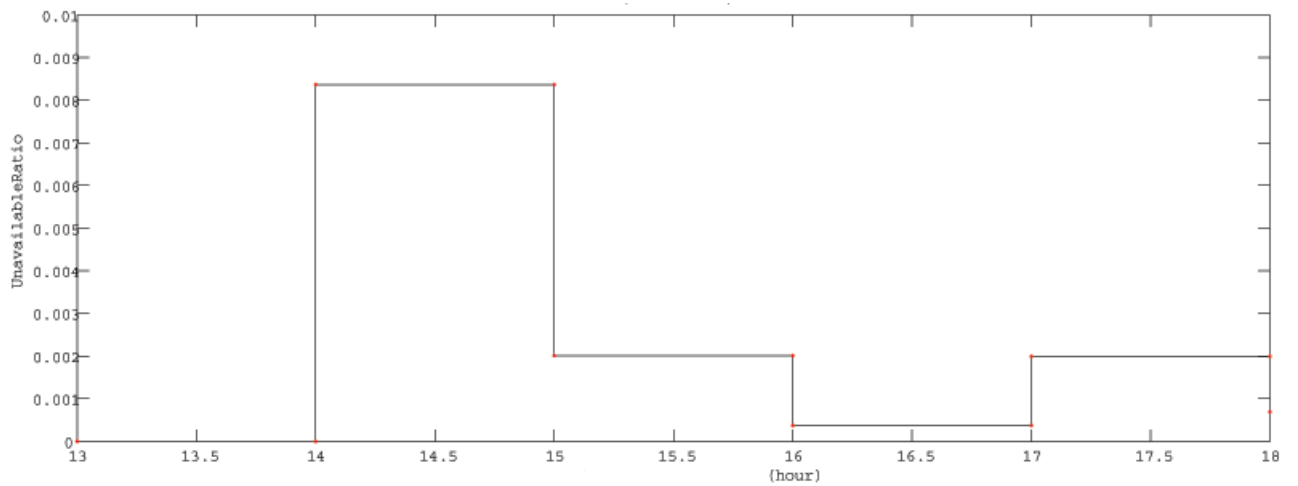
We can apply our data process also to the indoor measurements scenario to compute the unavailable Ratio R but in time slots of hours instead of every 5 mints in this case become the total period time for computing the ration every one hour 60 mints. we start with the single link of the indoor scenario figure 4-2. The results for this scenario have been computed for following three single links:

$$PC1 \Longleftrightarrow PC6, PC7 \Longleftrightarrow PC12, PC13 \Longleftrightarrow PC18$$

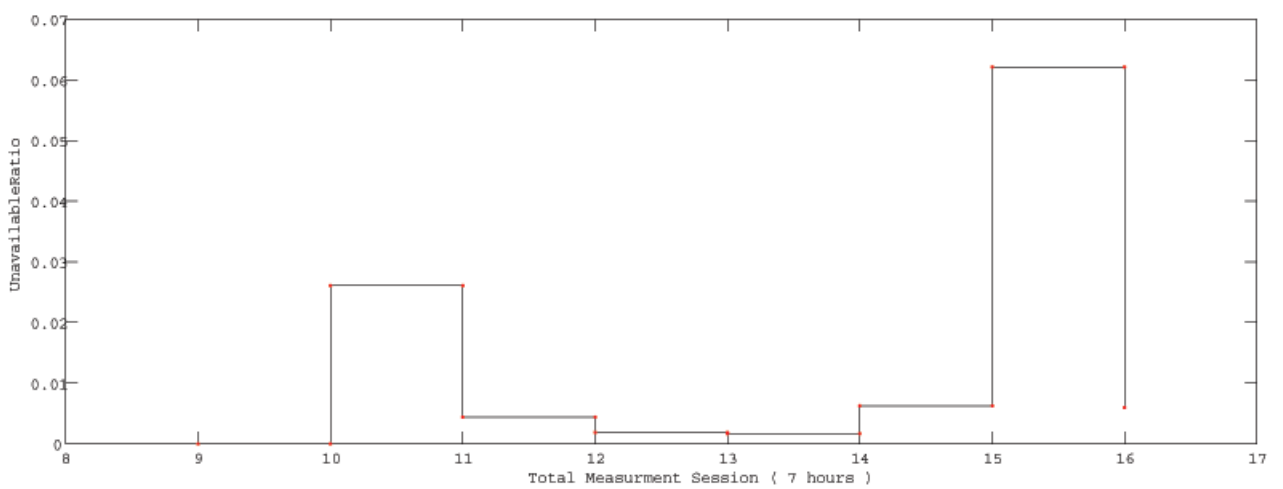
The results of the first link unavailable ration look as follow:



(a) PC1 ↔ PC6 Link first session



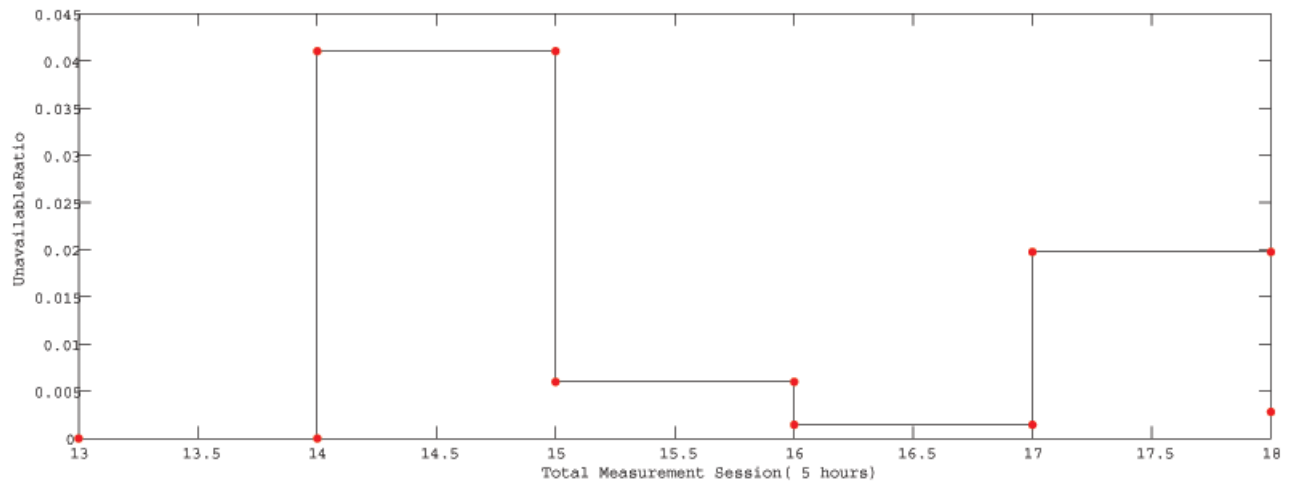
(b) PC1 ↔ PC6 Link second session



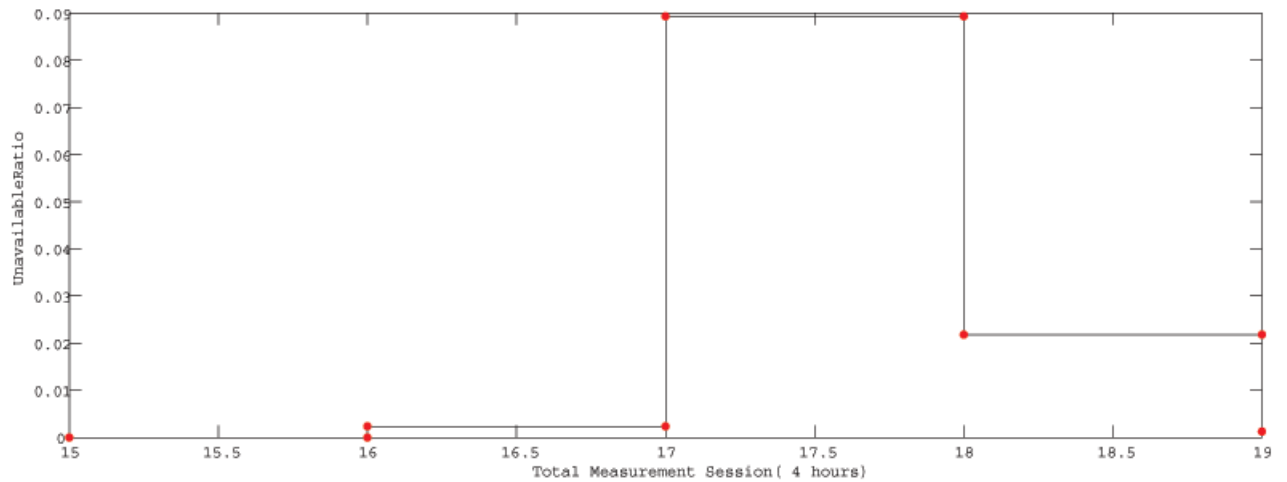
(c) PC1 ↔ PC6 Link Morning session

Figure 5-16: PC1 ↔ PC6 Link Measurements Results

The second unavailable ration single Link result are



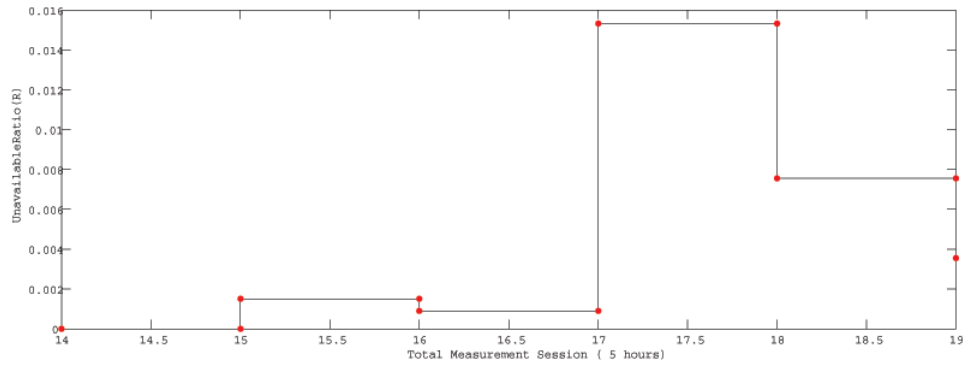
(a) PC7 \leftrightarrow PC12 Link first session



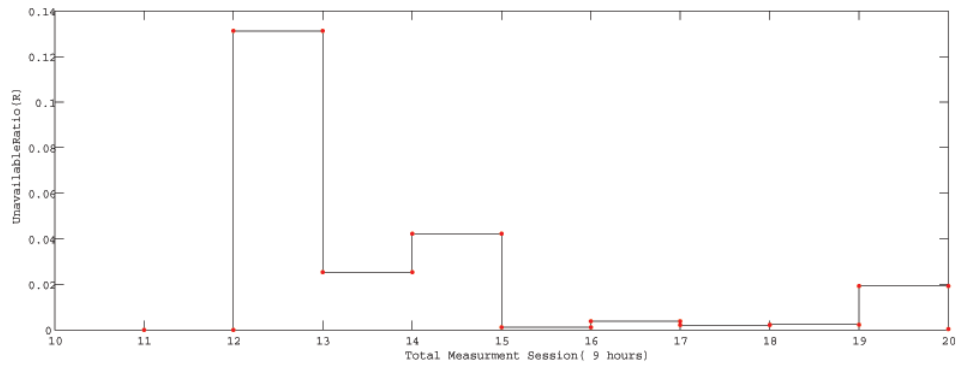
(b) PC7 \leftrightarrow PC12 Link second session

Figure 5-17: PC7 \leftrightarrow PC12 Link Measurements Results

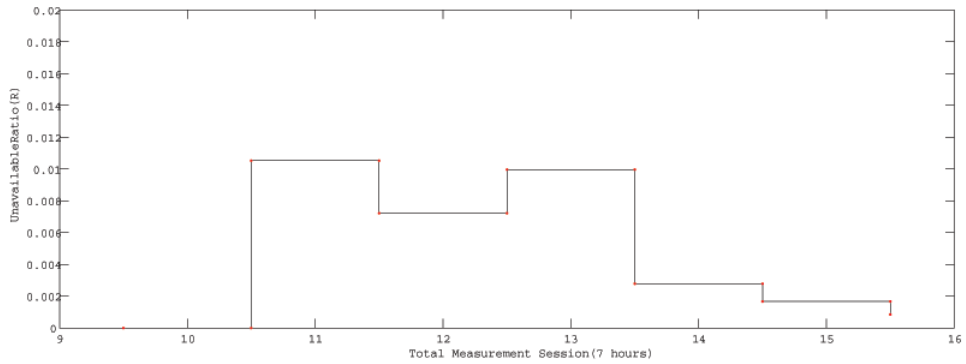
The last single link results are as follow:



(a) PC13 ↔ PC18 Link first session



(b) PC13 ↔ PC18 Link second session

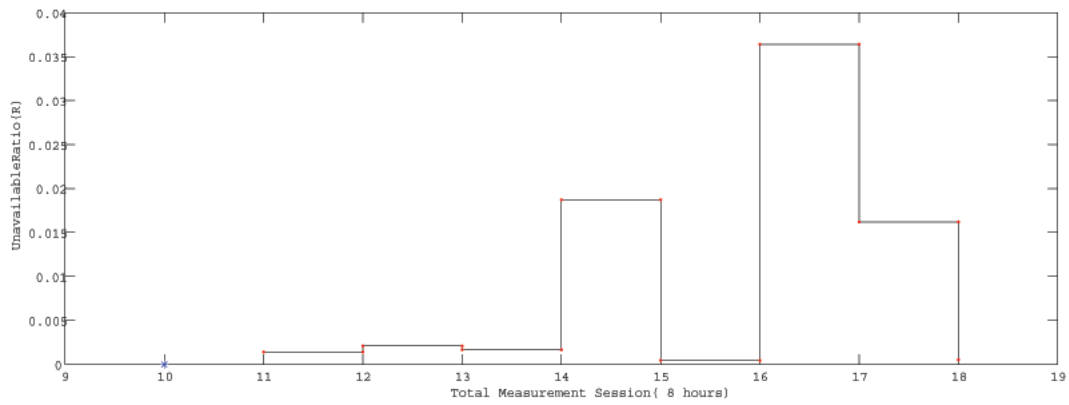


(c) PC13 ↔ PC18 Link Morning session

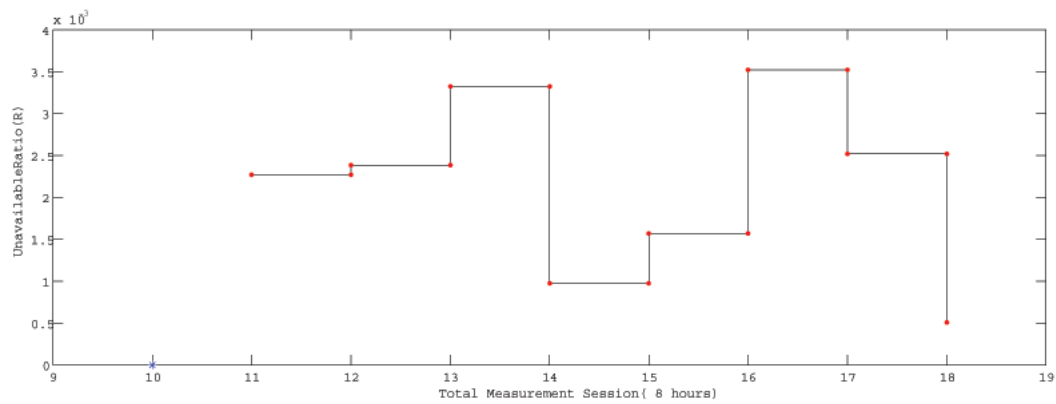
Figure 5-18: PC13 ↔ PC18 Link Measurements Results

The second part of our indoor Measurements is the two device measurements of figure 4-3. The session in this part of scenario is quite long therefore we are computing the unavailable ratio also every hour to study the influence of the students activity

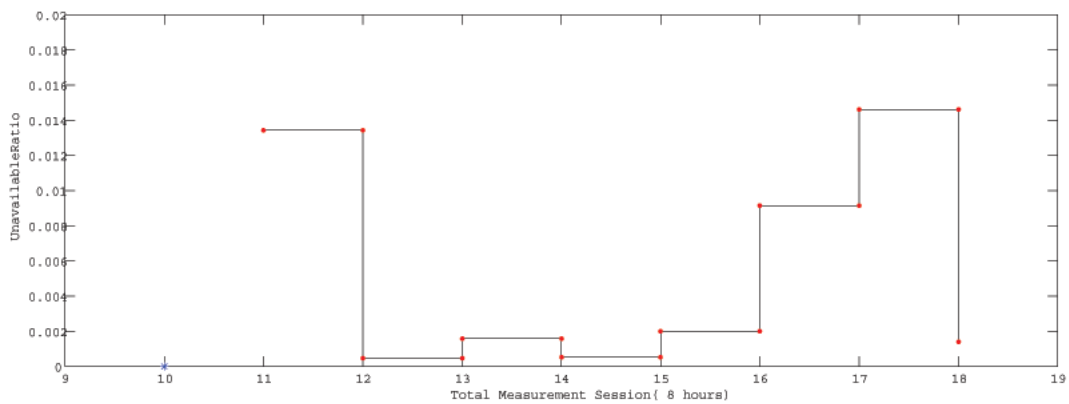
in different time slots. We have in this part two Links to measure one link between an access point from about 290cm height from the ground and PC 12, we can call it PC12-Access Link, the other is a single link between PC12 and PC7. We started this scenario half way April and we could log average 6 hours data activities in a day, these days are April 16, April 17, April 20, April 21, April 22, April 23, April 24, April 28, April 29, May 14, May 15, and May 18. Both devices were active during the session and we could log data from two links at the same time in two different data files. The unavailable ratio Results for both links ,PC12-Access and PC12-PC7 Link over the above logged data could give us some information about the regularity of people movements. The next few plots show the results of the unavailability ratio in different time slots, we tried to do measurements early in the morning and it was also important to do some measurements at the afternoon or after 16.00 when the activity of most students start again to increase leaving the room. Also we can see some regularity towards some time slots, like early at the morning when people start to come or at the lunch time when students start to leave the room having a break. Further the activities during the day are very independent, student's personal breaks or needs to leave the room is simply a random process. The results for the entire scenario look as follow:



(a) April 16th session(10.00-18.00)

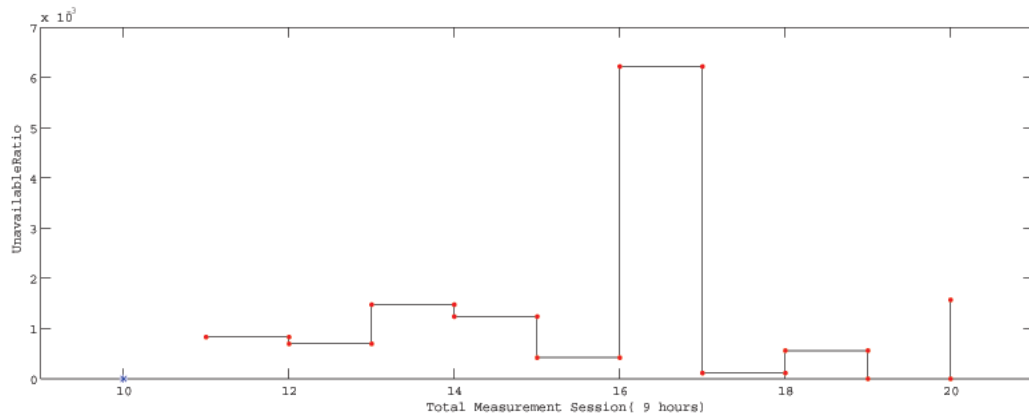


(b) April 17th session(10.00-18.00)

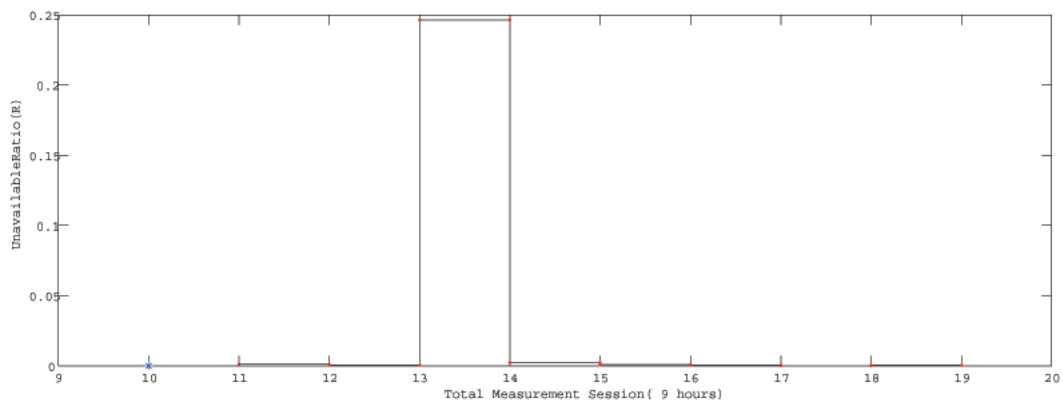


(c) April 22sd session()

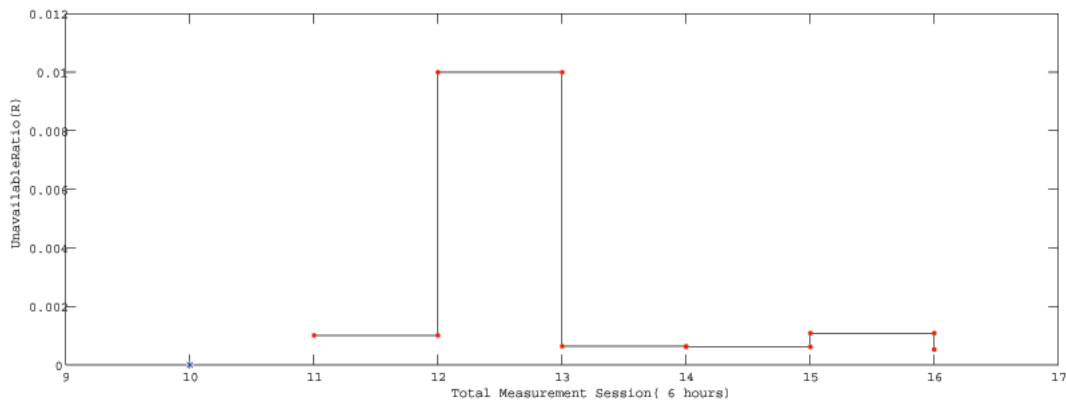
Figure 5-19: April Measurements Results PC12-Access Wall Link



(a) April 24th session(10.00-20.00)

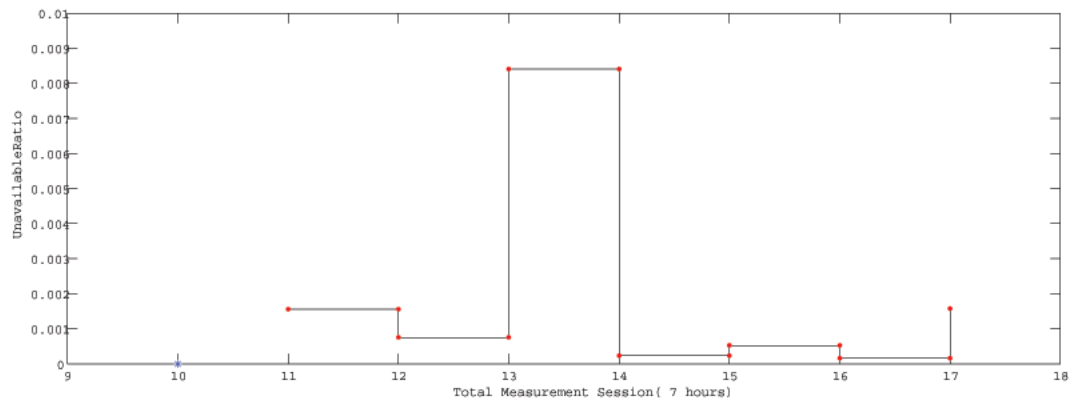


(b) April 28th session(10.00-19.00)

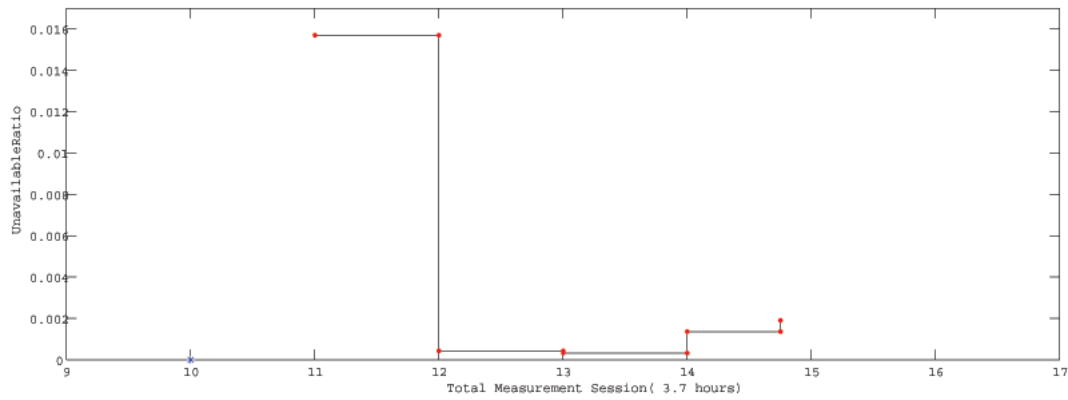


(c) April 29th session(10.00-16.00)

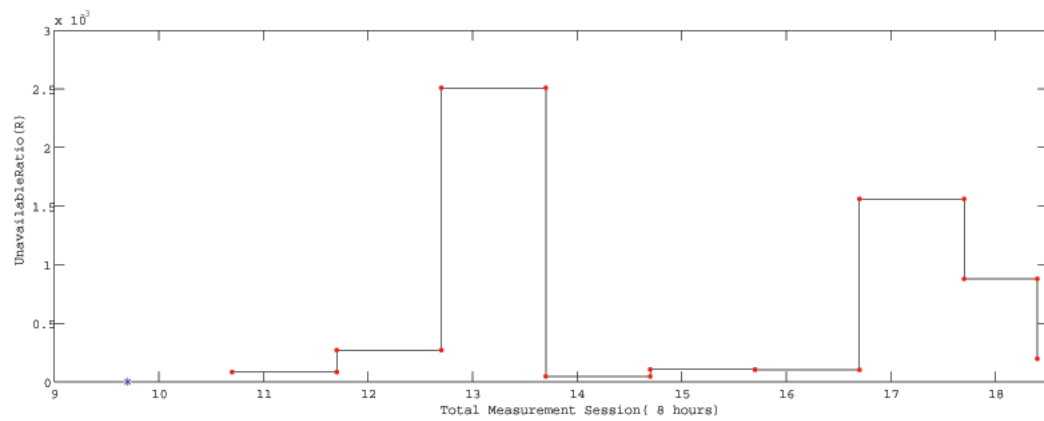
Figure 5-20: April Measurements Results PC12-Access Wall Link



(a) May 14th session(10.00-17.00)

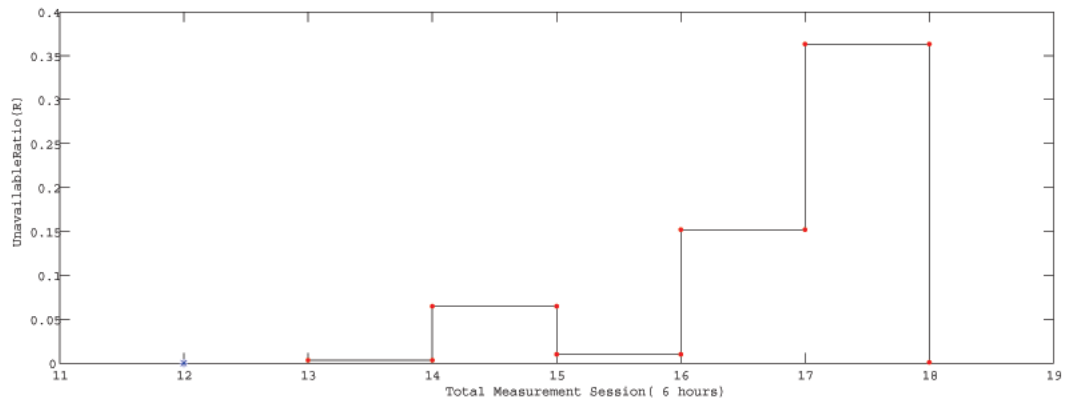


(b) May 15th session()

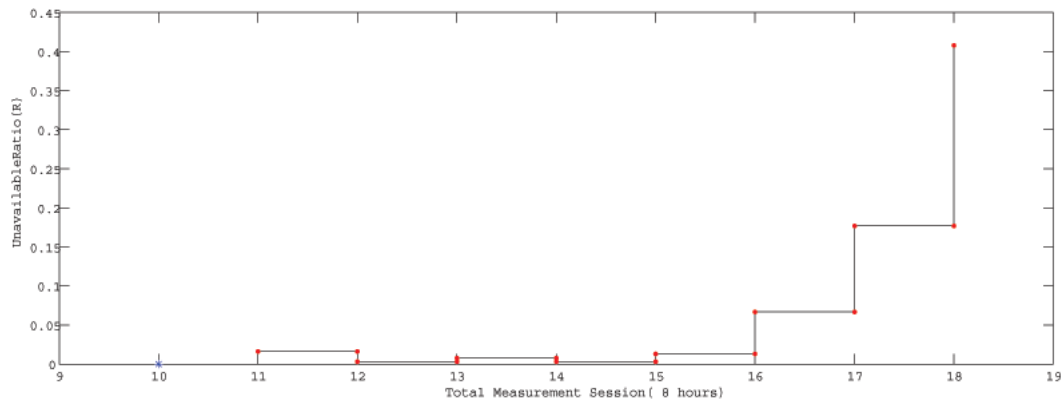


(c) May 18th session(9.40-18.25)

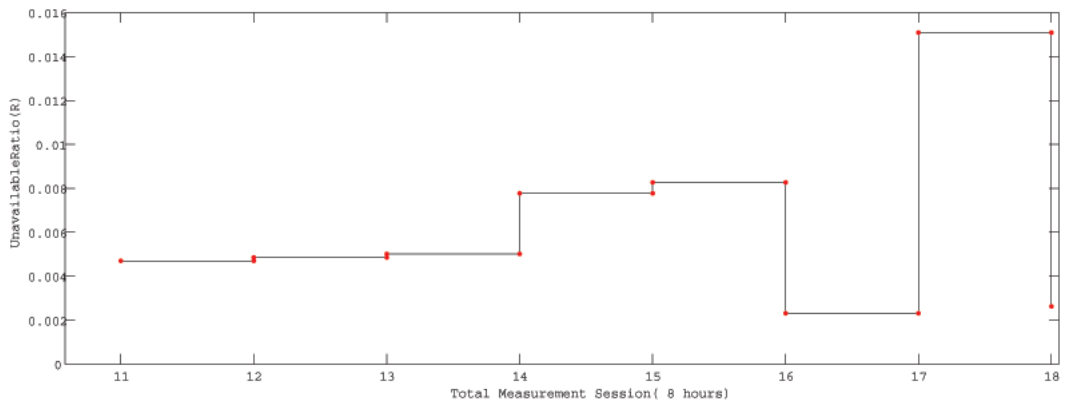
Figure 5-21: May Measurements Results PC12-Access Wall-Link



(a) April 16th session(10.00-18.00)

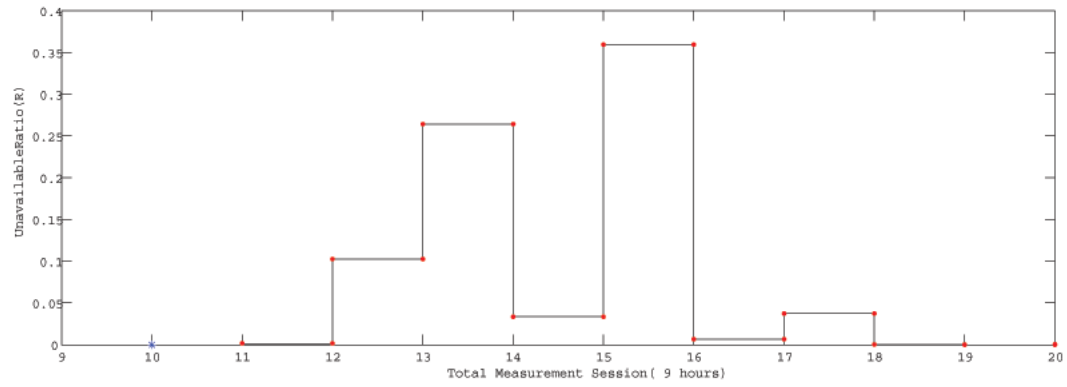


(b) April 17th session(10.00-18.00)

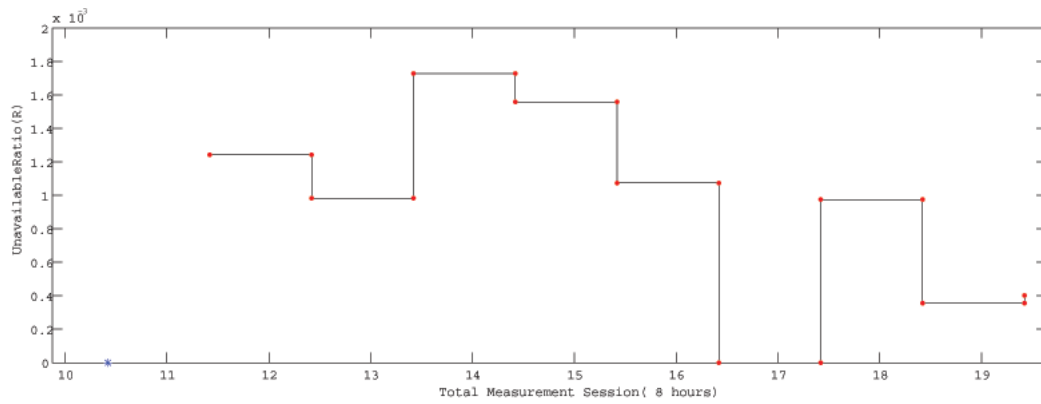


(c) April 21st session()

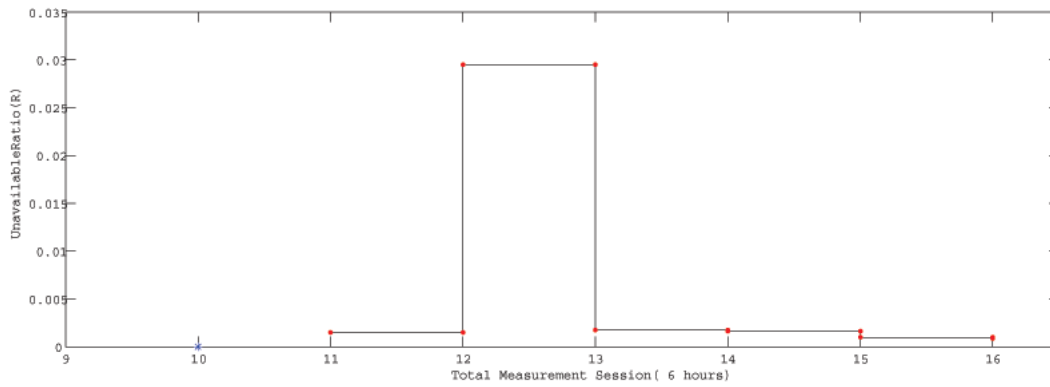
Figure 5-22: April Measurements Results PC12-PC7 Link



(a) April 24th session(10.00-20.00)

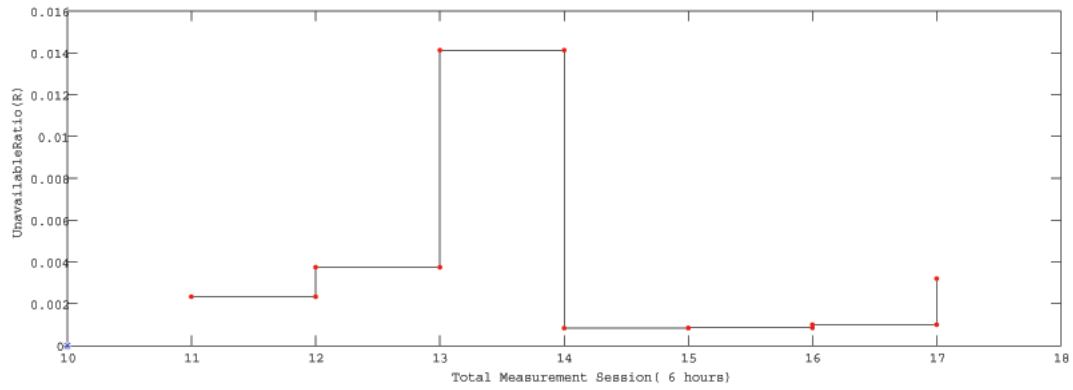


(b) April 28th session(10.00-19.00)

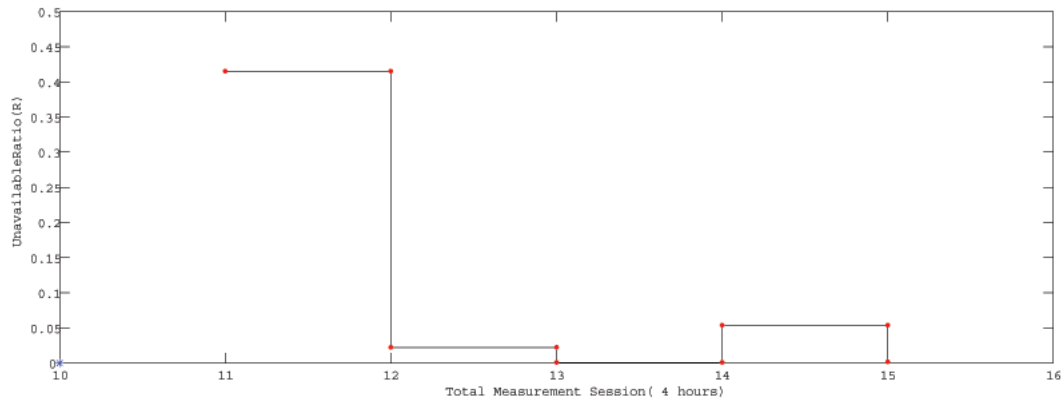


(c) April 29th session(10.00-16.00)

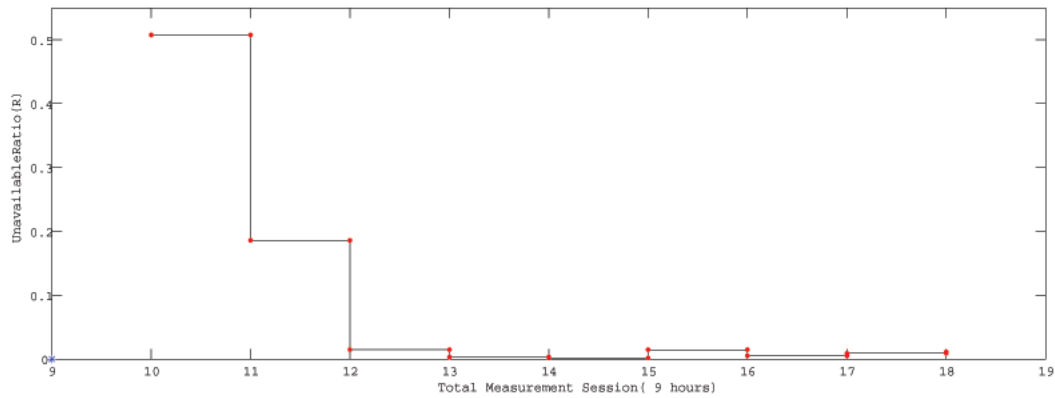
Figure 5-23: April Measurements Results PC12-PC7 Link



(a) May 14th session(10.00-17.00)



(b) May 15th session()



(c) May 18th session(9.40-18.25)

Figure 5-24: May Measurements Results PC12-PC7 Link

5-2 Phase B

In this phase we will compute the empirical CDF for the shadow that have been created as well as for the student's arrival time. Also we compute the maximum and the minimum for every single day data of the indoor scenario, the shadow and the student's arrival time mean can be also for the indoor scenario computed. Further we do that also for the both scenario's namely the indoor and the trial one.

5-2-1 Trial Measurements Results Phase B

The shadow empirical-cdf for the entire trial scenario look as follow:

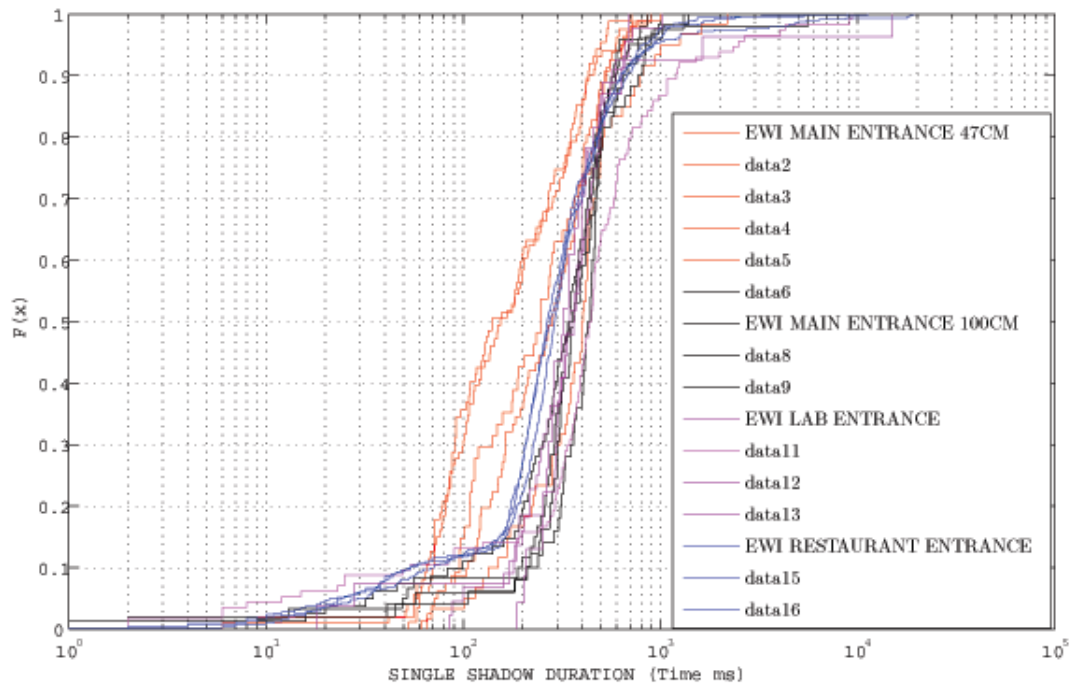


Figure 5-25: Shadow Empirical CDF for the Entire Trial Scenario

While the empirical cdf for the student's arrival time look as follow:

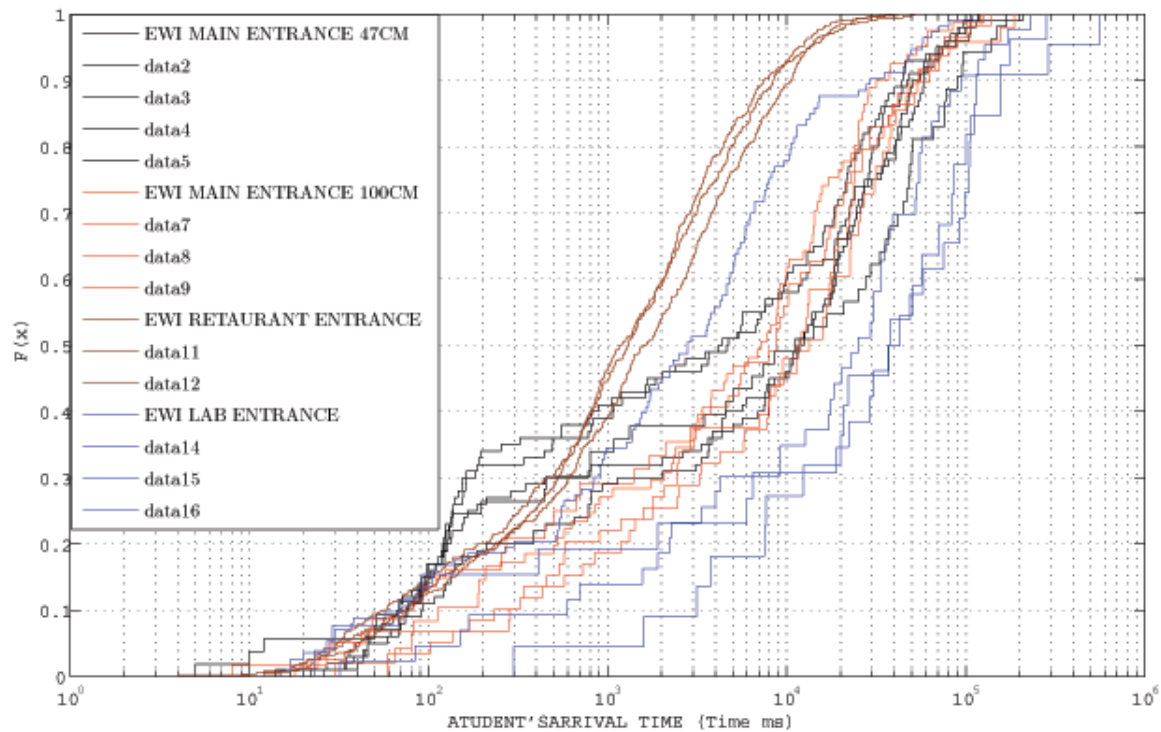


Figure 5-26: Student's Arrival Time Interval Empirical CDF For The Entire Trial Scenario

From the cdf-shadow we can't say much about the people the people's traffic leaving or entering a building, except they have quite similar behavior generally when they get close to an exit-entrance activity. The average speed of people leaving or entering a building is generally quite close to each other. Something is also noticeable that the channel or the link by the EWI entrance can behave differently by two different transmitter-sender height. By 47cm height we can notice that the link recover time after shadow is much smaller than by 100cm, it has to do with the area or the thickness of the human's body part that makes the shadow. For example your knee can make shorter shadow than your waist. By the Arrival interval we can see by the EWI restaurant that the arrival interval is much shorter than by the other two cases of the scenario, and that make also possible because during lunch time they are plenty of people who walk through the link after each other, so the chance that they cut the link behind each other during lunch time is much bigger than by entering a building. There will be no doubt that the situation will be exactly the other way around late in the evening when people start to leave the EWI building where no the chance is too small to find some one in the restaurant.

5-2-2 Indoor Measurements Result Phase B

The results for the one device single links can also shown and look as follow:

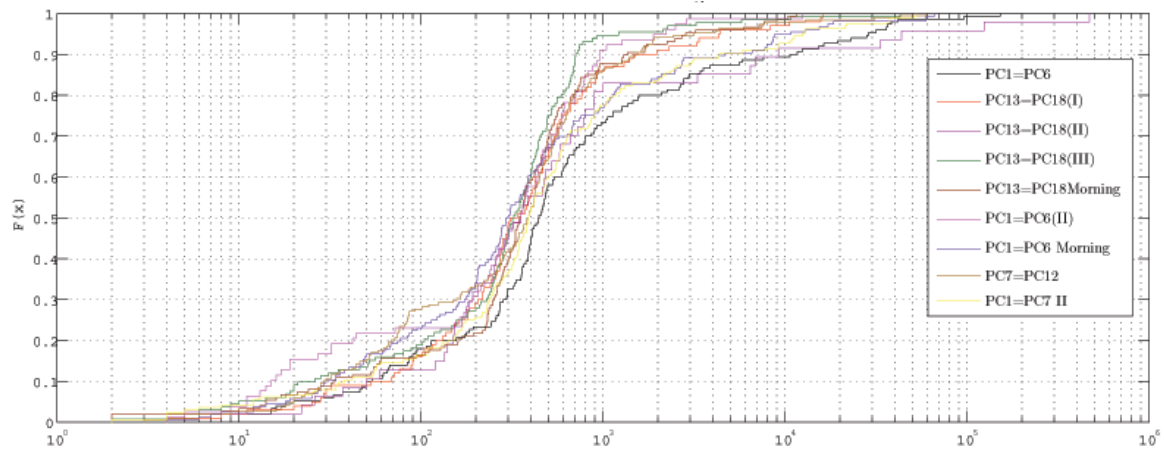


Figure 5-27: Shadow Empirical CDF for the One device Indoor Scenario

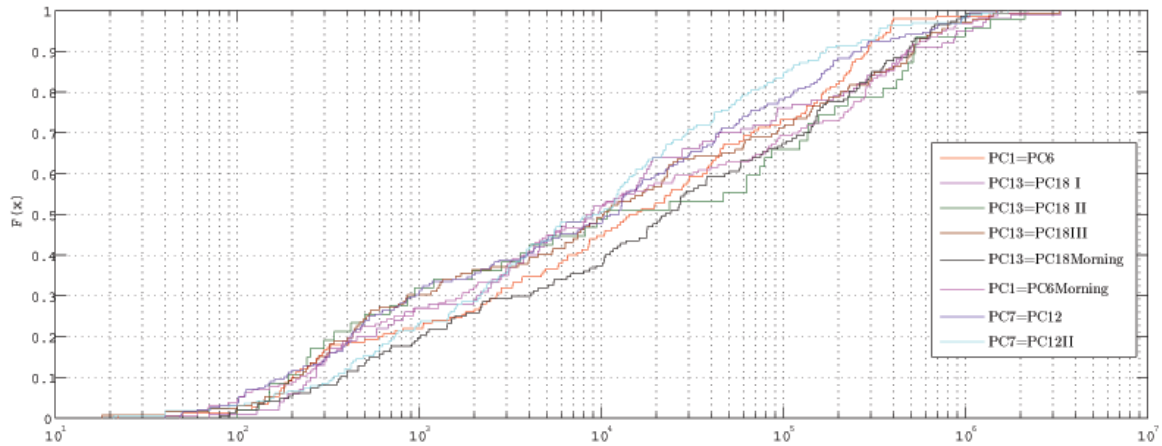


Figure 5-28: Student's Arrival Time Interval Empirical CDF for the One device Indoor Scenario

The X axis in figure5-27 is the duration of a single shadow(ms), while the X axis in figure5-28express the Arrival time interval(ms)

For the two devices scenario the shadow empirical cdf look as follow:

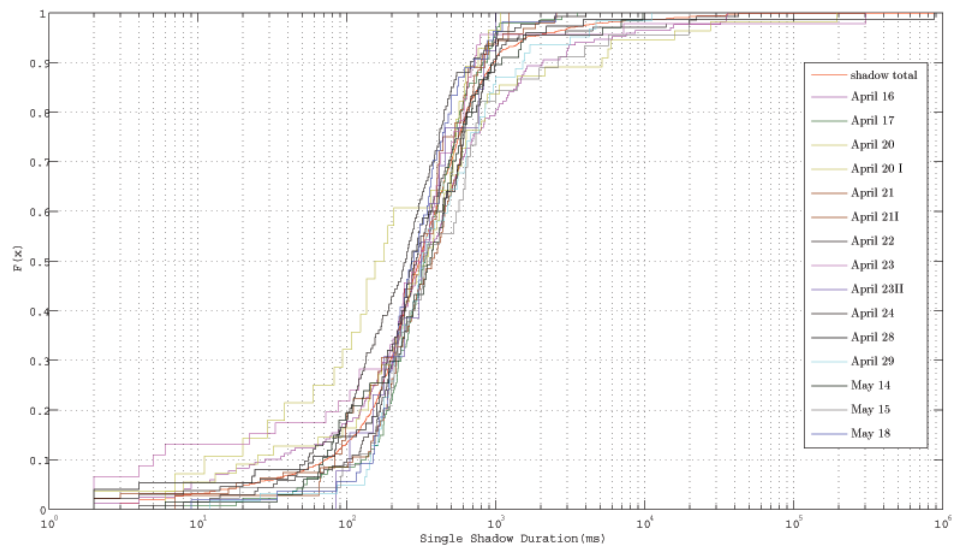


Figure 5-29: Shadow Empirical CDF for PC12-Wall Access point of the Two devices Indoor Scenario

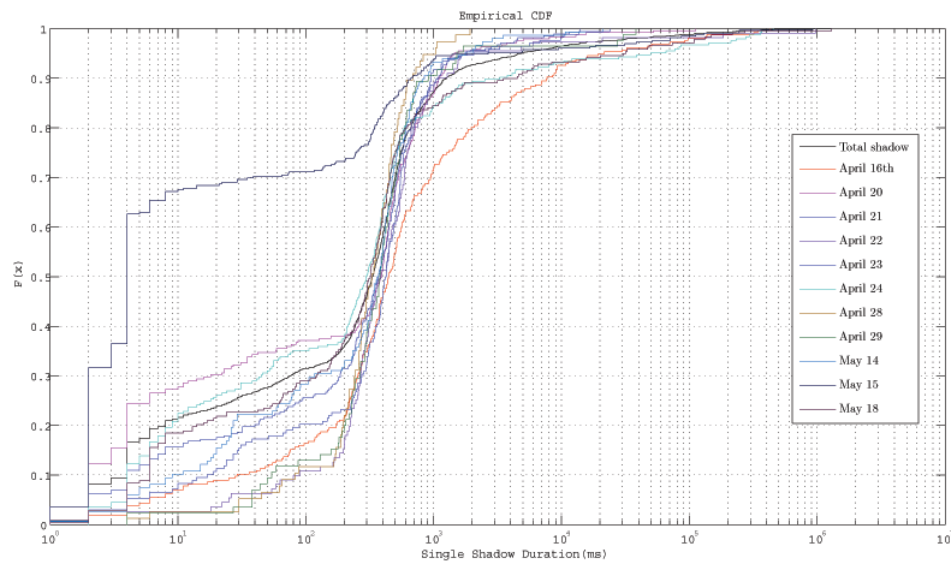


Figure 5-30: Shadow Empirical CDF for PC12-PC7 of the Two devices Indoor Scenario

The maximum and the minimum shadow that have been measured during the measurements days for the entire scenario look as follow:

Table 5-1: Shadow Duration, Mean, Max, and Min values for PC12-Access Point Link

Day	Mean(s)	Max(s)	Min(s)
April 16	0.7158	9.6	0.006
April 17	1.5384	19.6	0.016
April 20	0.4343	4.5	0.008
April 21	4.9622	193.9	0.002
April 22	1.1251	42.5	0.004
April 23	7.0571	303.03	0.002
April24	0.3552	3.9	0.005
April 28	12.1050	874.0	0.006
April 29	0.7974	112.1	0.012
May 14	1.6481	35.6	0.002
May 15	1.5384	19.9	0.004
May 18	0.3794	2.5	0.009

Table 5-2: Shadow Duration, Mean, Max, and Min values for PC12-PC7 Link

Day	Mean(s)	Max(s)	Min(s)
April 16	8.3573	427.29	0.010
April 20	1.2639	122.80	0.001
April 21	0.6673	13.91	0.009
April 22	11.1184	968.6	0.001
April 24	0.8559	23.38	0.008
April 28	0.3890	1.92	0.001
April29	1.5322	38.12	0.021
May 14	0.6354	20.90	0.004
May 15	6.3748	920.29	0.006
May 18	11.4012	1294.9	0.008

while the Arrival time interval for the both links look as follow:

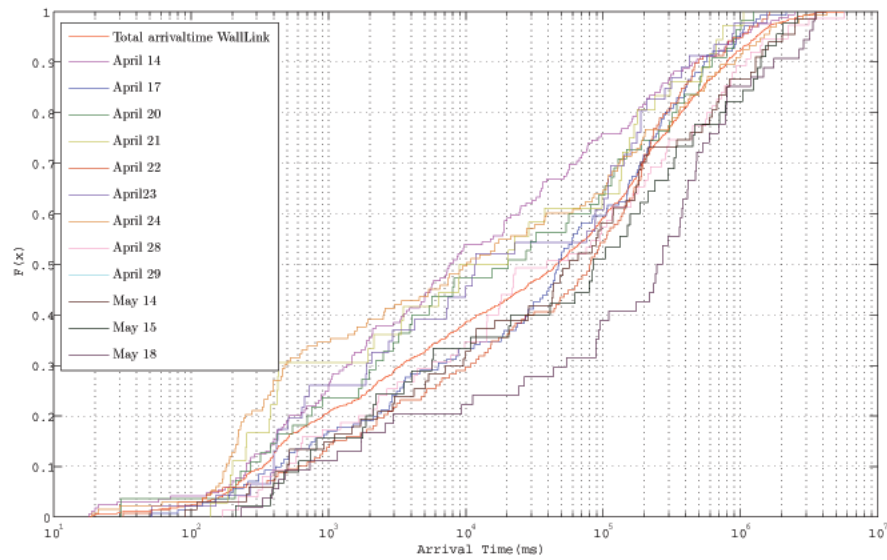


Figure 5-31: Arrival Time Interval Empirical CDF for PC12-Wall Access point of the Two devices Indoor Scenario

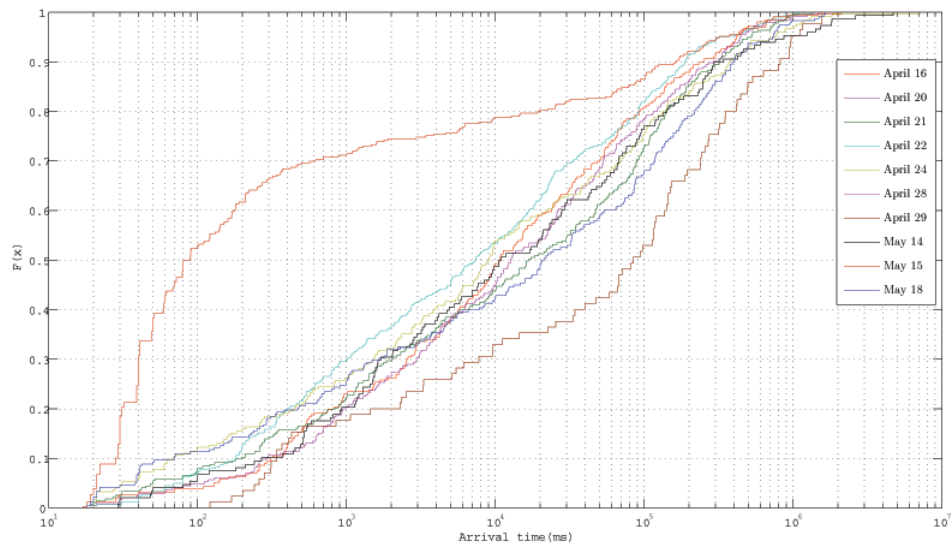


Figure 5-32: Arrival Time Interval Empirical CDF for PC12-PC7 of the Two devices Indoor Scenario

Also the Arrival time interval have been computed and for the both links, the mean, max, and the minimum look as follow.

Table 5-3: Arrival Time Mean, Max, Min values Link PC12-Wall Access point

Day	Mean(s)	Max(s)	Min(s)
April 16	161.5896	2472.6	21
April 17	195.8816	2153.5	51
April 20	226.8044	1490.3	21
April 21	214.9614	1700.4	85
April 22	201.1881	1614.3	32
April 23	207.5227	1566.6	51
April 24	265.6989	4226.6	19
April 28	388.8613	5671.2	168
April 29	318.8213	2889.2	182
May 14	379.5729	2561.2	90
May 15	399.4283	2596.6	210
May 18	579.5607	3468.5	232

Table 5-4: Arrival Time Mean, Max, Min values link PC12-PC7

Day	Mean(s)	Max(s)	Min(s)
April 16	78.187	1182.570	20
April 20	90.5583	1496.090	18
April 21	103.2467	1351.10	19
April 22	67.7741	1094.50	21
April 24	144.2504	7122.20	18
April 28	233.5481	1546.10	121
April 29	133.5481	1364.50	20
May 14	172.6106	4684.70	21
May 15	56.7375	2110.90	16
May 18	138.2794	1648.80	18

Analyzing the data and fit the logged data in an given distribution model will take place in the next two phases. we will try to analyze and find a suitable distribution model if possible to the logged data of the two devices scenario.

5-3 Phase C

In the next Phase we will try to find a wide range of distributions fits, and check what if any of these distribution can fit, for all logged data of the indoor measurements scenario devices. we do that using EasyFit. EasyFit allows easily and quickly to select the probability distribution which have best fit to data, and perform specific calculations using the best 55 Supported Distributions fitting model. EasyFit use also the The goodness of fit (GOF) tests to measure the compatibility of a random sample with a theoretical probability distribution function. In other words, these tests show how well the distribution you selected fits to your data. Here are three methods to evaluate the GOF in EasyFit, The following GOF tests are supported: Kolmogorov-Smirnov, Anderson-Darling, and Chi-Squared. In our data fitting we will make use of the first method, Kolmogorov-Smirnov, during using EasyFit to fit our two devices scenario's Data.

The KolmogorovSmirnov test (KS test) is a form of minimum distance estimation used as a nonparametric test of equality of one-dimensional probability distributions used to compare a sample with a reference probability distribution. Also to compare two samples (two-sample KS test).

The KolmogorovSmirnov statistic quantifies a distance between the empirical distribution function of the sample and the cumulative distribution function of the reference distribution, or between the empirical distribution functions of two samples. The goodness-of-fit test or the KolmogorovSmirnov test is constructed by using the critical values of the Kolmogorov distribution, α .

EasyFit has an Excel add-in, enabling us to deal with uncertainty by analyzing our probability data right in Excel. Which makes processing the work much easier by loading the Arrival time interval data or even the shadow duration for one day data, for example, in an excel file and export it to EasyFit to analyze it. The Arrival time interval of the indoor measurements data have been loaded in the EasyFit software to process it and finding the right distribution's fitting for each data have been logged in the period April till May.

The indoor one device, single links, results and the two devices links results show different distribution's fitting during data processing in EasyFit. Although we try to show some results of particular sort distribution that have been strongly present in almost all the logged data of both student's room scenarios. Here we show some results for the most frequent distribution's fitting that strongly presents in arrival time interval data of the one device indoor scenario.

DISTRIBUTION	PC1=PC6	PC1=PC6 Morning	PC1=PC6II	PC13=PC18 I	PC13=>PC1 8 II	PC13=>PC1 8 III	PC13=>PC1 8 Mor	PC7=PC12	PC7=PC12 II
Weibull(3p) Kolmogorov-Smirnov	$\alpha=0,44781$ $\beta=43102,0$ $\gamma=22,0$	$\alpha=0,37007$ $\beta=51917,0$ $\gamma=48,0$	$\alpha=0,37096$ $\beta=1,1002E+5$ $\gamma=22,0$	$\alpha=0,36359\beta$ $=33078,0$ $\gamma=70,0$	$\alpha=0,36569$ $\beta=56950,0$ $\gamma=100,0$	$\alpha=0,37254$ $\beta=39864,0$ $\gamma=18,0$	$\alpha=0,42072$ $\beta=51369,0$ $\gamma=81,0$	$\alpha=0,40541\beta$ $=29617,0$ $\gamma=40,0$	$\alpha=0,41774$ $\beta=23077,0$ $\gamma=21,0$
	α <u>0.2</u> 0.1 <u>0.02</u> <u>0.01</u> <u>0.05</u>	α <u>0.02</u> 0.01 <u>0.05</u>	α <u>0.2</u> 0.1 <u>0.02</u> <u>0.01</u> <u>0.05</u>	α <u>0.2</u> 0.1 <u>0.02</u> <u>0.01</u> <u>0.05</u>	α <u>0.2</u> 0.1 <u>0.02</u> <u>0.01</u> <u>0.05</u>	α <u>0.1</u> <u>0.02</u> <u>0.01</u> <u>0.05</u>	α <u>0.2</u> 0.1 <u>0.02</u> <u>0.01</u> <u>0.05</u>	α <u>0.02</u> <u>0.01</u> <u>0.05</u>	α <u>0.1</u> <u>0.02</u> <u>0.01</u> <u>0.05</u>
Weibull	$\alpha=0,45195$ $\beta=37777,0$	$\alpha=0,3965$ $\beta=43890,0$	$\alpha=0,35623$ $\beta=88440,0$	$\alpha=0,41538\beta$ $=36944,0$	$\alpha=0,35982$ $\beta=50203,0$	$\alpha=0,39906\beta$ $=37929,0$	$\alpha=0,45418$ $\beta=56883,0$	$\alpha=0,43379\beta$ $=27218,0$	$\alpha=0,50531$ $\beta=22683,0$
	α 0.2 0.1 0.02 0.01 0.05	α 0.02 0.1 0.01 0.05	α 0.2 0.1 0.02 0.01 0.05	α 0.1 0.02 0.01 0.05	α 0.2 0.1 0.02 0.01 0.05	α 0.1 0.02 0.01 0.05	α 0.2 0.1 0.02 0.01 0.05	α 0.02 0.1 0.01	α 0.2 0.1 0.02 0.01 0.05
LogPearson3	$\alpha=40,396$ $\beta=0,41809$ $\gamma=26,213$	$\alpha=2018,8$ $\beta=0,06613$ $\gamma=142,81$	$\alpha=11,285$ $\beta=0,98063$ $\gamma=20,956$	$\alpha=131,83$ $\beta=0,24437$ $\gamma=22,987$	$\alpha=838,13$ $\beta=0,10791$ $\gamma=99,862$	$\alpha=11900,$ $\beta=0,02709$ $\gamma=331,51$	$\alpha=46,476$ $\beta=0,38762$ $\gamma=27,752$	$\alpha=1460,9$ $\beta=0,07188$ $\gamma=113,94$	$\alpha=2125,5$ $\beta=0,05226$ $\gamma=120,02$
	α 0.2 0.1 0.02 0.01 0.05	α 0.02 0.1 0.01 0.05	α 0.1 0.02 0.01 0.05	α 0.2 0.1 0.02 0.01 0.05	α 0.2 0.1 0.02 0.01 0.05	α 0.1 0.02 0.01 0.05	α 0.2 0.1 0.02 0.01 0.05	α 0.02 0.1 0.01 0.05	α 0.2 0.1 0.02 0.01 0.05

Table 5-5: Single Links One device Student's Room Scenario frequent distribution's fitting , α, β, γ are the distribution parameters

The best frequent distribution fitting results for the arrival time interval data, using EasyFit software for the indoor measurements two device scenario, look as follow:

Table 5-6: Fitting Distribution Results PC12-PC7 Single Link

Weibull(3P)	<u>APRIL 16</u> $\alpha=0.42954$ $\beta=30082.0$ $\gamma=20.0$	<u>APRIL 20</u> $\alpha=0.41075$ $\beta=17828.0$ $\gamma=18.0$	<u>APRIL 20A</u> $\alpha=0.5201$ $\beta=57218.0$ $\gamma=30.0$	<u>APRIL 21</u> $\alpha=0.40476$ $\beta=33494.0$ $\gamma=19.0$	<u>APRIL 22</u> $\alpha=0.38957$ $\beta=14525.0$ $\gamma=19.0$	<u>APRIL 22A</u> $\alpha=0.51956$ $\beta=66082.0$ $\gamma=40.0$
	α	α	α	α	α	α
	0.2	0.2	0.2	0.01	0.01	0.2
	0.1	0.1	0.1			0.1
	0.02	0.02	0.02			0.02
	0.01	0.01	0.01			0.01
	0.05	0.05	0.05			0.05
	<u>April 24</u> $\alpha=0.3528$ $\beta=40480.0$ $\gamma=19.0$	<u>April 28</u> $\alpha=0.33673$ $\beta=1.3801E+5$ $\gamma=80.0$	<u>April 29</u> $\alpha=0.43103$ $\beta=1.0916E+5$ $\gamma=121$	<u>May 14</u> $\alpha=0.39086$ $\beta=43495.0$ $\gamma=29.0$	<u>May 15</u> $\alpha=0.27358$ $\beta=2065.6$ $\gamma=17.0$	<u>May 18</u> $\alpha=0.37535$ $\beta=45146.0$ $\gamma=18.0$
	α	α	α	α	α	α
	0.02	0.1	0.1	0.2	0.2	0.2
	0.01	0.02	0.02	0.1	0.1	0.1
	0.05	0.01	0.01	0.02	0.02	0.02
		0.05	0.05	0.01	0.01	0.01
				0.05	0.05	0.05

Weibull	<u>APRIL 16</u> $\alpha=0.48743$ $\beta=29386.0$	<u>APRIL 20</u> $\alpha=0.46487$ $\beta=17987.0$	<u>APRIL 20A</u> $\alpha=0.52444$ $\beta=59887.0$	<u>APRIL 21</u> $\alpha=0.43158$ $\beta=40388.0$	<u>APRIL 22</u> $\alpha=0.4519$ $\beta=12749$	<u>APRIL 22A</u> $\alpha=0.52754$ $\beta=61344.0$
	α	α	α	α	α	α
	0.02	0.2	0.2	0.02	0.2	0.2
	0.01	0.1	0.1	0.01	0.1	0.1
		0.02	0.02	0.05	0.02	0.02
		0.01	0.01		0.01	0.01
		0.05	0.05		0.05	0.05
	<u>April 24</u> $\alpha=0.39735$ $\beta=30833.0$	<u>April 28</u> $\alpha=0.39871$ $\beta=1.6436E+5$	<u>April 29</u> (3p) $\alpha=0.42072$ $\beta=1.1943E+5$	<u>May 14</u> $\alpha=0.43653$ $\beta=38847.0$	<u>May 15</u> $\alpha=0.30074$ $\beta=2793.4$	<u>May 18</u> $\alpha=0.38193$ $\beta=47615.0$
	α	α		α	α	α
	0.2	0.2		0.2	0.2	0.2
	0.1	0.1		0.1	0.1	0.1
	0.02	0.02		0.02	0.02	0.02
	0.01	0.01		0.01	0.01	0.01
	0.05	0.05		0.05	0.05	0.05

Table 5-7: Fitting Distribution Results For PC12-Wall Access Point Link

Weibull(3P)	<u>APRIL14</u> $\alpha=0.38025$ $\beta=39956.0$ $\gamma=18.0$ α 0.02 0.01 0.05	<u>APRIL17</u> $\alpha=0.45649$ $\beta=1.0059E5$ $\gamma=51.0$ α 0.2 0.1 0.02 0.01 0.05	<u>APRIL 20</u> $\alpha=0.3869$ $\beta=74606$ $\gamma=20.0$ α 0.2 0.1 0.02 0.01 0.05	<u>APRIL 21</u> $\alpha=0.41186$ $\beta=96603.0$ $\gamma=80.0$ α 0.02 0.01	<u>APRIL 22</u> $\alpha=0.49748$ $\beta=1.1374E+5$ $\gamma=32.0$ α 0.2 0.1 0.02 0.01 0.05	<u>APRIL 23</u> $\alpha=0.41211$ $\beta=81454.0$ $\gamma=52.0$ α 0.2 0.1 0.02 0.01 0.05
	<u>April 24</u> $\alpha=0.41211$ $\beta=81454.0$ $\gamma=52.0$ α 0.2 0.1 0.02 0.01 0.05	<u>April 28</u> $\alpha=0.38266$ $\beta=1.2006E+5$ $\gamma=168.0$ α 0.2 0.1 0.02 0.01 0.05	<u>April 29</u> $\alpha=0.4090$ $\beta=1.4297E+5$ $\gamma=90.0$ α 0.2 0.1 0.02 0.01 0.05	<u>May 14</u> $\alpha=0.40902$ $\beta=1.4297E+5$ $\gamma=90.0$ α 0.2 0.1 0.02 0.01 0.05	<u>May 15</u> $\alpha=0.40731$ $\beta=1.2748E+5$ $\gamma=210$ α 0.2 0.1 0.02 0.01 0.05	<u>May 18</u> $\alpha=0.50161$ $\beta=3.1493E+5$ $\gamma=232$ α 0.2 0.1 0.02 0.01 0.05

Weibull(2P)	<u>APRIL14</u> $\alpha=0.41537$ $\beta=35516.0$ α 0.02 0.01	<u>APRIL17</u> $\alpha=0.45115$ $\beta=92945.0$ α 0.2 0.1 0.02 0.01 0.05	<u>APRIL 20</u> $\alpha=0.3754$ $\beta=83498.0$ α 0.2 0.1 0.02 0.01 0.05	<u>APRIL 21</u> $\alpha=0.39087$ $\beta=1.0327E+5$ α 0.02 0.01 0.05	<u>APRIL 22</u> $\alpha=0.4596$ $\beta=1.1036E+5$ α 0.2 0.1 0.02 0.01 0.05	<u>APRIL 23</u> $\alpha=0.39851$ $\beta=81729.0$ α 0.2 0.1 0.02 0.01 0.05
	<u>April 24</u> $\alpha=0.39851$ $\beta=81729.0$ α 0.2 0.1 0.02 0.01 0.05	<u>April 28</u> $\alpha=0.40637$ $\beta=1.2134E+5$ α 0.2 0.1 0.02 0.01 0.05	<u>April 29</u> (no match)	<u>May 14</u> $\alpha=0.41443$ $\beta=1.3195E+5$ α 0.2 0.1 0.02 0.01 0.05	<u>May 15</u> $\alpha=0.3985$ $\beta=1.5845E+5$ α 0.2 0.1 0.02 0.01 0.05	<u>May 18</u> $\alpha=0.41474$ $\beta=3.3146E+5$ α 0.2 0.1 0.02 0.01 0.05

The shadow Data from the Indoor measurements scenario have been also processed in EasyFit, but the results express no connections between the fitted distributions results, each day shadow data fits different distribution than the day after or before, and the one good fit in one data shadow can be very bad choice for the day after or before. Therefore there is no single distribution can fit the entire shadow data that we have been collected from both indoor scenarios.

For the arrival time interval is quite obvious that the Weibull(3or2 parameters) distribution model have fitted all the logged data in different scales. For example table 5-6 and table 5-7 show that the Weibull distribution fits all the arrival time interval data with different KolmogorovSmirnov parameter. The tables also determine two α the first one is the Weibull fitting parameters while the second one is the KolmogorovSmirnov parameter who decide the goodness of the fitting. KolmogorovSmirnov α has five values to evaluate the goodness of the fitting (0.2, 0.1, 0.02, 0.01, 0.05), how more α values fit in the goodness fitting test how better is the distribution model fitting the given data.

But From the telecommunications point of view, analytical model such as Markov chain is based on the assumption that the occurrence of the events can be modelled as Poisson process with the interval of the two consecutive events follows the exponential distribution. Fitting the arrival interval help us to find out what if our observation on the people interrupting LOS has the exponential distributed interval. The exponential model is basically not fitting our data well in way the Weibull model obviously does, but that will make us keep looking for a mathematical model that can be close to the exponential model from one hand and fit the arrival time interval well from the other. Unfortunately customize a mathematical model can not be done with Easyfit, Therefore we will do process and analyze our a mathematical model further in the last phase using Matlab.

5-4 Phase D

Customizing a mathematical model needs to implement the MLE in order to find the right parameters for the chosen distribution model that have been selected in the MLE process. MLE can be implemented using Matlab software by simply indicating the sort distribution model and the confidence level(α) in the package formula to compute the parameters.

But before using Matlab, we try to evaluate the difference between the Matlab executed MLE results and the computed results of EasyFit so far, we will compute first the Weibull parameters using Matlab MLE method and the confidence level for the arrival time interval of the wall access point link.

If both software distribution's parameters(α, β) belong to the same confidence level, then we would see close values of the same parameters executed in two different software, which let us compare and evaluate the results of MLE Matlab software with what we have found so far in EasyFit. The next table show us the Weibull distribution parameters executed in two different software:

Table 5-8: Weibull Distribution's Parameters Test. (α, β) are EasyFit Distribution Parameters, a, b are Matlab Distribution Parameters)

April 14	April 17	April20	April 21
$\alpha=0.41537$ $\beta=35516.0$ a = 0.3764 b=39513.6 conf.level 25.8474 0.3355 60.4055 0.4222	$\alpha=0.45115$ $\beta=92945.0$ a= 0.4706 b=96191.5 conf.level 66.4863 0.4121 139.1687 0.5376	$\alpha=0.3754$ $\beta=83498.0$ a=0.4012 b=87679.4 conf.level 49.8443 0.3368 154.2338 0.4780	$\alpha=0.39087$ $\beta=1.0327E+5$ a= 0.4364 b=101878.9 conf.level 67.4400 0.3786 153.9043 0.5031
April 22	April 23	April24	April28
$\alpha=0.39087$ $\beta=1.0327E+5$ a= 0.4996 b=111350.4 conf.level 78.3943 0.4362 158.1609 0.5724	$\alpha=0.39851$ $\beta=81729.0$ a= 0.4257 b=87221.3 conf.level 46.3536 0.3463 164.1203 0.5233	$\alpha=0.39851$ $\beta=81729.0$ a= 0.3355 b= 54785.9 conf.level 32.0470 0.2937 93.6592 0.3832	$\alpha=0.40637$ $\beta=1.2134E+5$ a= 0.4067 b=131987.1 conf.level 73.3087 0.3405 237.6334 0.4859
April 29	May 14	May15	May18
$\alpha=0.47269$ $\beta=1.3848E+5$ a= 0.4771 b=152029.3 conf.level 87.6314 0.3921 263.7513 0.5804	$\alpha=0.41443$ $\beta=1.3195E+5$ a= 0.4216 b=144692.9 conf.level 79.4439 0.3488 263.5324 0.5096	$\alpha=0.3985$ $\beta=1.5845E+5$ a= 0.4316 b=171598.9 conf.level 84.0451 0.3409 350.3615 0.5465	$\alpha=0.41474$ $\beta=3.3146E+5$ a= 0.4971 b=325793.4 conf.level 185.5926 0.3990 571.9049 0.6192

the results of table shows a similarity of the values of the both parameters of two different software, for example Weibull parameter α in April 14th computed by EasyFit software is equal to 0.41537 which is a very close value to parameter a (0.3764) if we implement Weibull using Matlab MLE method. Therefore we can conclude that parameter α in EasyFit is equal to a in Matlab and β is actually b for the same Weibull distribution. The confidence level of April 14th for the α , a parameters is between 0.3355 and 0.4222, while the confidence level for parameter β and b between 25.8474-60.4055(s), while β , b are in (ms).

5-5 Phase E

After showing the parameters similarity in both software we can go from this point to customize our mathematical model using Matlab knowing the fact that EasyFit can't customize a mathematical model unless it have been established in his library. Once again we try to customize a model that have an exponential behavior to model our arrival time interval according to it. we will try to fit our data in the following mathematical pdf model:

$$PDF = p \lambda_1 \exp^{-x \lambda_1} + (1 - p) \lambda_2 \exp^{-x \lambda_2}$$

- p : is the probability of the model.
- λ_1, λ_2 : are the parameters of the exponential distribution, often called the rate parameter. $\lambda \geq 0$ determines how frequent the event occurs.

Test the goodness of fitting results for the mathematical model using MLE method in Matlab will take place via using the the sum of the Square Errors(SSE). SSE is a method of regression analysis. The line on a graph that best summarizes the relationship between two variables is the one that ensures that there is the least value of the sum of the squares of the deviation between the fitted curve and each of the original data points. The best fit in the least-squares sense is that instance of the model for which the sum of squared residuals has its least value. a residual being the difference between an observed value and the value given by the mode.

By programing our mathematical model in Matlab software we also have computed the SSE for Weibull distribution and exponential distribution as a way to evaluate our model performance comparing to the best fit already known by EasyFit(Weibull) and the to the exponential distribution which we want to reach with our custom model. We have fitted our indoor measurements two devices Arrival interval time data to the custom model, like we have already said we have been using MLE method via Matlab to implement the custom model fitting, at the very same time we have also been fitting the data to Weibull and exponential distribution in order to compute the SSE of both distribution's model. Finally we compare the SSE of the three distribution's models to check what if our model preforms better.

The results of the SSE check after fitting the Arrival time interval data to it look as follow:

Table 5-9: SSE for fitting Arrival interval time single link PC12-PC7 of the custom, Weibull and the exponential distributions models

SSE	April 16	April 20	April 21	April 22	April 24
Custom mathematical model	0.6430	0.5722	0.5365	1.2761	1.1651
exponential distribution model	14.3945	13.1630	11.7421	26.0793	10.2450
Weibull distribution model	0.1529	0.1431	0.3626	0.4714	0.7129
SSE	April 28	April 29	May14	May15	May18
Custom mathematical model	0.1824	0.1750	0.7557	0.5380	0.6430
exponential distribution model	2.2832	2.8322	12.6669	12.9665	14.3859
Weibull distribution model	0.2159	0.2495	0.1596	0.2114	0.1520

Table 5-10: SSE for fitting Arrival interval time PC12-Wall Access point of the custom, Weibull and the exponential distributions models

SSE	April 14	April 17	April 20	April 21	April 22	April 23
Custom mathematical model	0.6199	0.3847	0.1558	0.1091	0.2202	0.1200
exponential distribution model	14.8315	4.7022	3.7533	3.4374	3.0923	2.3297
Weibull distribution model	0.3595	0.1861	0.1995	0.6375	0.2542	0.2479
SSE	April 24	April 28	April 29	May14	May15	May18
Custom mathematical model	0.6479	0.2432	0.1535	0.3518	0.1491	0.2481
exponential distribution model	10.4353	4.4560	2.8116	3.7997	1.9794	1.1357
Weibull distribution model	0.5162	0.1327	0.0730	0.0794	0.1186	0.1622

Reading the result's tables we can easily notice that the Weibull distribution have the smallest SSE value, but also we can see that the exponential distribution have quite large SSE value, therefore it's not the right distribution fitting. But If we consider the custom mathematical model that we introduced earlier in this phase we see that the SSE value is quite small comparing that to the Weibull distribution SSE values. The custom model is the sum of two exponential distribution's function which will give us in his turn the exponential behavior that we are looking for to fit the data in.

Conclusion And Future Work

6-1 Conclusion

The 60 GHz Communications has a promising feature to provide ultra high data rate wireless links. Although 60 GHz is not suited for long range communication due to atmospheric absorption, high path loss and attenuation by various objects, it is very well suited for indoor environment. The indoor kind of network does not cover a large area. The propagations of signals in 60 GHz band can easily be blocked by people, walls, furnitures. This poses serious challenging to the designer of an indoor network operating at the 60 GHz band.

Our goal is to study the effect or the influence of human's activities on the 60 GHz line of sight(LOS) communications in an indoor environment. In this thesis we are not interested in characterizing the 60GHz channel rather than the movement characterization and the blocking events process. Therefore we made a choice out three devices to emulate the 60 GHz antenna equipment and study the blocking events behavior more carefully. The device have been tested what if the direct LOS and the shadow event are close enough to the one made by the 60 GHz band considering that both transmitter and receiver are non mobile devices.

Two major scenarios have been set, one to have a flavour over the movement's similarity of people Entering or Exiting a building, namely by three places(EWI Main Entrance,EWI Lab building and the EWI Restaurant). During our measurements there by two different transmitter-receiver heights from the ground namely 47 cm and 100 cm, we noticed that the LOS can recover from blocking events faster than when the shadow made by 100 cm devices height. By lower device height, people block the LOS in general with their thin part (legs), if u consider for sure adults working through the gates, which is much different when u go more than twice that height by 100 cm facing people waist or chest when they walk through blocking the LOS.

A second scenario have been set namely the student's room indoor scenario which we measured different single links between the student's PCs using one pair device emulator, and the second time with two pair device measuring one single link PC12-PC7 and at the same time measuring from an access point at 290 cm from the wall making link contact with PC 12 figure 4-3

The collected data have been processed and analyzed using different softwares programs, first we started with EasyFit to find out what if our data fit one of the established general distribution model, The shadow duration data could not fit any of the established general distribution model and therefor we have been concentrating on the arrival time interval data because the last have been fitting quite well in a model that can be presented(Weibull), and it is quite important for us to in vestige what if interrupting LOS has the exponential distributed arrival time interval, for that reason we have been also studying the ability to find a custom model that can be close to the exponential distribution behavior in a way that this custom mathematical model will fit our data as good or may a bit less as the Weibull distribution does. The model is processed and implemented using MLE method using Matlab programing. The test of the implemented model(SSE value)has been compared with two other tests (SSE fitting Weibull and exponential distributions using also MLE method by Matlab), and the results shows that the custom model can FIT the arrival time interval of the indoor scenarios two devices WELL. Weibull distribution stay the best fitted model for the arrival time interval, but the custom model is the sum of two in depended exponential distribution models which can give us the behavior that we are looking for in order to be more useful from implementation from the telecommunications point of view.

6-2 Future Work

The time for the future work can be reserved for more investigating on the shadow duration, we did measure the shadow but we no specific distribution model we could find that fits the shadow well. Therefore more investigation and data logging might here be required. More shadows can take us to the idea of more data collection with more different scenario, may be also by comparing two students room together(from different floors) and find out what if that also can have some similarity, therefore more data might add more information.

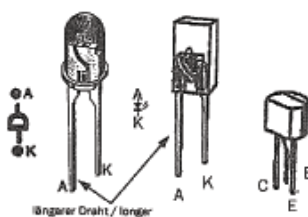
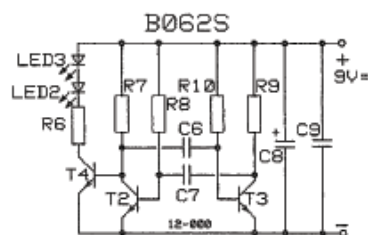
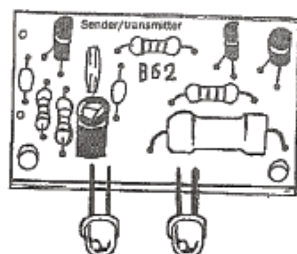
Appendix A

Appendix

A-1 Infrared Barrier Devices

The infrared device (transmitter -receiver) components and the manuals are easy to find with every device, we have used two infrared devices of two different LOS distances. building the devices should n't take much time in case u have all the components ready, although some Conrad packets have such unique IC component that u can't easy find in any electronics shop these days, Therefore u have to be very careful by ordering the device. The manuals for both devices and the components description look as fallow:

- (a) 15M LOS INFRARED DEVICE: Afm.: (lxb) 55 mm x 44 mm,
Uitvoering: Bouwpakket, Aansluitvermogen: 3 A/35 V/DC Max.
bereik: 15 M, Schakelcontact: 1 x aan, Voedingsspanning: 9 V=
ontvanger 12 V/DC
- (b) 5M LOS INFRARED DEVICE:
Audible (85dB) and visible (LED) alert
Range: 3.3ft to 13ft
On/Off switch provided
Power supply: Transmitter: 9V DC / 50mA max. Receiver: 9V DC
/ 20mA max.
9V battery holder and adapter jack included
Dimensions:
Transmitter: 2.2" x 1.6"
Receiver: 3.9" x 2.0"



Stückliste Empfänger:

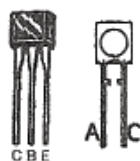
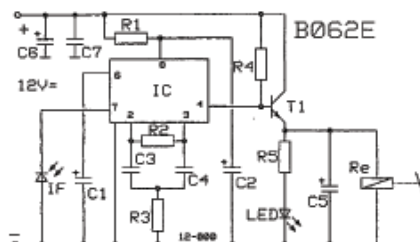
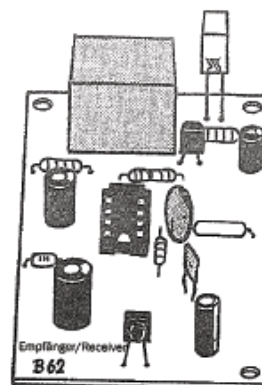
IC	: 1 IC U2531
IF	: 1 IC-Fassung dazu 8-polig
T1	: 1 Transistor SC238 oder BC237 oder BC547
LED	: 1 Leuchtdiode gelb
C1	: 1 Elko 10µF
C2,C6	: 2 Elkos 100µF 25V
C3	: 1 Kondensator 4,7nF (4n7)
C4	: 1 Kondensator 39pF (39K oder 39P)
C5	: 1 Elko 4,7µF
C7	: 1 Kondensator 100nF (104)
RE	: 1 Relais 12V 1 x EIN
R1	: 1 Widerstand 309 Ohm oder 374 Ohm
R2	: 1 Widerstand 150 k Ohm (braun-grün-schwarz-orange...)
R3	: 1 Widerstand 1,1 k Ohm (1K1)
R4	: 1 Widerstand 5 k 6 (grün-blau-rot...)
R5	: 1 Widerstand 432 Ohm (gelb-orange-rot-schwarz...)

1 Platine vergoldet, ca. 55 x 44 mm

Stückliste Sender:

T2,T3	: 2 Transistoren SS216 oder BC547
T4	: 1 Transistor SF829 oder BC337
LED2,LED3	: 2 Infrarot-Leuchtdioden TSHA 5201
C6,C9	: 2 Kondensatoren 100nF (104)
C7	: 1 Kondensator 4,7nF (4n7)
C8	: 1 Elko 4,7µF
R6	: 1 Widerstand 12 Ohm oder 15 Ohm 3W
R7	: 1 Widerstand 1 k 1 Ohm (1K1)
R8,R10	: 2 Widerstände 10 k (braun-schwarz-orange...)
R9	: 1 Widerstand 22 k Ohm (rot-rot-schwarz-rot...)

1 Platine vergoldet, ca. 23 x 45 mm



<http://www.kemo-electronic.de>
Kemo Germany 12-000 / B062 / v002

Parts list receiver:

IC	: 1 IC U2531
IF	: 1 IC-socket, eight-pole
T1	: 1 infrared receiver diode with filter S268P
T2	: 1 transistor SC238 or BC237 or BC547
LED	: 1 light diode yellow
C1	: 1 elco 10µF
C2,C6	: 2 elcos 100µF 25V
C3	: 1 capacitor 4,7nF (4n7)
C4	: 1 capacitor 39pF (39K or 39P)
C5	: 1 elco 4,7µF
C7	: 1 capacitor 100nF (104)
RE	: 1 relay 12V 1 x ON
R1	: 1 resistance 309 Ohm or 374 Ohm
R2	: 1 resistance 150 k Ohm (brown-green-black-orange...)
R3	: 1 resistance 1,1 k Ohm (1K1)
R4	: 1 resistance 5 k 6 (green-blue-red...)
R5	: 1 resistance 432 Ohm (yellow-orange-red-black...)

1 gold-plated board, approx. 55 x 44 mm

Parts list transmitter:

T2,T3	: 2 transistors SS216 or BC547
T4	: 1 transistor SF829 or BC337
LED2,LED3	: 2 infrared light diodes TSHA 5201
C6,C9	: 2 capacitors 100nF (104)
C7	: 1 capacitor 4,7nF (4n7)
C8	: 1 elco 4,7µF
R6	: 1 resistance 12 Ohm or 15 Ohm 3W
R7	: 1 resistance 1 k 1 Ohm (1K1)
R8,R10	: 2 resistances 10 k Ohm (brown-black-orange...)
R9	: 1 resistance 22 k Ohm (red-red-black-red...)

1 gold-plated board, approx. 23 x 45 mm

D Die beiden Platinen werden gemäß der Zeichnungen bestückt. Die Empfängerplatine muß so montiert werden, daß die gewölbte Linse der Infrarot-Diode "IF" freie Sicht auf den Sender hat. Der Empfänger benötigt eine gut gefilterte Gleichspannung von 12V, ca. 100mA, die entweder aus einem Netzteil oder einer Batterie entnommen wird. Der Sender benötigt eine Spannung von ca. 9V bei einem Strombedarf von ca. 50...80mA. Wenn Batterien verwendet werden, so müssen diese ausreichend groß sein um den Strom von ca. 100mA abgeben zu können! Die kleinen 9V Transistorbatterien sind zu klein bei einem evtl. Dauerbetrieb! Die beiden Infrarot-Leuchtdioden des Senders müssen beide in Richtung der Empfängerdiode "IF" zeigen! Je größer die Entfernung ist, desto genauer müssen die LED-Sendediode in die Richtung des Empfängers ausgerichtet werden. Wenn der Sender in Richtung des Empfängers strahlt, leuchtet die LED des Empfängers auf und das Relais zieht an. Durch Verwendung von Optiken oder Sammellinsen vor dem Sender und Empfänger kann die Reichweite der Lichtschranke noch wesentlich verstärkt werden. Wird der Empfänger starker Sonneneinstrahlung ausgesetzt, empfehlen wir, die IR-Empfängerdiode "IF" mit einem Röhrchen gegen Streulicht von hinten und von den Seiten zu schützen. Die Öffnung des Röhrchens muß dann in Richtung auf den Sender ausgerichtet sein. Das Röhrchen sollte von innen matt schwarz sein, siehe Zeichnung.

Las dos placas de circuito se equipan según el dibujo. La placa de circuito del receptor se debe montar de manera que la lente abovedada del diodo infrarrojo "IF" se encuentre en vista libre al emisor. El receptor necesita una tensión continua bien filtrada de 12V, aprox. 100mA que está suministrada por una fuente de alimentación o por una batería. El emisor necesita una tensión de aprox. 9V con un consumo de corriente de aprox. 50...80mA. ¡En caso de servicio de batería, es importante que las baterías son demasiado eficientes para producir una corriente de aprox. 100mA! ¡Las pequeñas baterías de transistores 9V son demasiado débiles para un funcionamiento permanente! Los dos diodos luminosos infrarrojos del emisor tienen que ser en dirección al diodo del receptor "IF"! Lo más larga la distancia, lo más exacto los LED-diodos del emisor deben ajustar en la dirección del receptor. Si el emisor radia en la dirección del receptor, el LED del receptor se enciende y el relé atrae. El uso de ópticas y lentes colectoras delante del emisor y receptor podrá extender el alcance de la barrera de luz infrarroja considerablemente. Si el receptor está sujeto a una irradiación solar fuerte, recomendamos de proteger el IR-diodo del receptor "IF" atrás y a todos lados con un tubo contra luz difusa. Entonces la abertura del tubo debe mostrar en la dirección del emisor. El interior del tubo debería ser negro mate, mirar el dibujo.

Les éléments seront montés suivant schémas sur les 2 platines. La platine récepteur doit être montée de telle sorte que la lentille convexe de la diode infra-rouges "IF" ait un champ de vision libre sur l'émetteur. Le récepteur a besoin d'une tension continue de 12V, env. 100mA, bien anti-parasitée qui peut provenir soit d'un bloc d'alimentation soit d'une batterie. L'émetteur quant à lui nécessite une tension d'env. 9V pour une consommation de courant d'env. 50...80mA. Si l'on utilise des piles, celles-ci doivent être suffisantes pour produire un courant d'env. 100mA! Les petites piles transistor de 9V seront trop faibles pour un fonctionnement en continu! Les 2 leds à infra-rouges de l'émetteur doivent être toutes deux dirigées vers la diode réceptrice "IF"! Plus la distance est grande, plus le réglage de la direction des diodes leds émettrices vers le récepteur devra être précis. Si l'émetteur émet en direction du récepteur, la led du récepteur brille et le relais s'enclenche. En utilisant des accessoires optiques et des lentilles convergentes devant l'émetteur et le récepteur, on pourra augmenter de façon importante le rayon d'action de la barrière optique. Si le récepteur est exposé à insolation forte, nous recommandons de protéger la IR-diode du récepteur "IF" à l'arrière et des côtés avec un tube contre lumière diffusée. Ensuite il faut que l'ouverture du tube montre en direction du transmetteur. L'intérieur du tube devrait être noir pôle voir le dessin.

FIN Molemmat pärlävyt kalustetaan pilustusten mukaisesti. Vastaanotinlevy on asennettava niin, että infrapunadiodin "IF" kaarevasta linssistä on vapaa näkyvyys lähettimelle. Vastaanotin tarvitsee hyvin suodatetun 12V, n. 100mA tasa virran, joka joko tulee verkkolaitteesta tai paristosta. Lähetin tarvitsee n. 9V jännitteen virtatarpeen ollessa n. 50...80mA. Jos käytät paristoja täytyy niiden olla tarpeeksi suuria voidakseen luovuttaa n. 100mA virran! Pienet 9V transistoriparistot ovat liian pienä käytön ollessa jatkuvaa. Lähettimen molempia infrapuna-LEDiä on suunnattava vastaanotindiodin "IF" suuntaan! Mitä suurempi etäisyys on, sitä tarkemmin on lähetin-LEDit suunnattava vastaanottimen suuntaan. Kun lähitin säteilee vastaanottimen suuntaan, sytty vastaanottimen LED ja rele vetää. Käyttämällä optiikkaa tai kokoomalinssejä lähettimen ja vastaanottimen edessä voidaan valoverran kantomatkaa vielä pidentää huomattavasti. Jos vastaanotin joutuu voimalkaan auringonsäteilyn kohteeksi, suosittelemme, että IR-vastaanotindiodi "IF" suojataan putkella takaa ja sivuilta hajavalloita. Putken aukko tulee silloin suunnata lähettimen suuntaan. Putki tulee olla sisästä mattamusta katso kuvaa.

GB Both printed wiring boards are equipped with the components following the figure. The receiver p.w. board has to be fixed that way that the transmitter is within the sight of the infrared diode "IF". The receiver needs a well filtered d.c. voltage of 12V, approx. 100mA, supplied by power pack or battery. The transmitter needs a voltage of 9V having a current supply of approx. 50...80mA. Using batteries it must be considered that they are sufficiently powerful to feed 100mA. Small 9V transistor batteries will not withstand in case of continuous operation! Both infrared light diodes of the transmitter must be adjusted to the diode of the receiver "IF"! The longer the distance, the more exactly the LED transmitting diodes have to be aligned with the receiver. Whenever the transmitter radiates in the direction of the receiver, the LED of the receiver will light up and the relay pulls up. Using optical or focus lenses in front of the transmitter and receiver may extend the range of the light barrier considerably. If the receiver is exposed to strong solar radiation, we recommend to protect the IR receiver diode "IF" from behind and laterally with a tube against light scatter. Then the opening of the tube must point into the direction of the transmitter. The inside of the tube should be matt black see drawing.

NL De onderdelen worden overeenkomstig de printplaten gemonteerd. De ontvangerprintplaat moet dusdanig gemonteerd worden, dat de gewölbde lens van de infrarooddiode "IF" vrij zicht naar de zender heeft. De ontvanger benodigt een goed afgevlakte gelijkspanning van 12V, ong. 100mA, die of uit een gelijkrichter, of uit een batterij wordt betrokken. De zender benodigt een spanning van ong. 9V bij een stroomopname van ong. 50...80mA. Wanneer batterijen gebruikt worden, dan moeten deze sterk genoeg zijn om de stroom van ong. 100mA te kunnen afgeven! De kleine 9V-transistorbatterijen zijn voor event. continuubedrijf te klein! De beide infrarood-LED's van de zender moeten beide in richting van de ontvangerdiode "IF" wijzen! Hoe groter de afstand is, des te nauwkeuriger moeten de LED-zenddiodes in de richting van de ontvanger gericht worden. Wanneer de zender in de richting van de ontvanger straalt, licht de LED van de ontvanger op en het relais trekt aan. Door gebruik van optieken of verzamellinzen voor de zender en de ontvanger kan de reikwijdte van de lichtbarrière/afstandsbediening nog belangrijk vergroot worden. Wordt de ontvanger aan sterke zoninstraling blootgesteld, bevelen wij aan, de IR-ontvangerdiode "IF" met een buisje van achteren en van de zijden tegen stroolicht te beschermen. De opening van het buisje moet dan in richting op de zender zijn gericht. Het buisje zou van binnen dofzwart moeten zijn zie tekening.

P Ambas as placas de circuito impresso devem ser montadas segundo a figura. A placa do receptor tem de ser fixa de modo a que o emissor esteja visível pelo diodo de infravermelhos. O receptor precisa de uma fonte de tensão DC bem filtrada de 12V, 100mA, de fonte de alimentação ou bateria. O emissor necessita de uma tensão de 9V tendo um consumo de 50 a 80 mA. Se quiser usar baterias tenha em atenção que têm de alimentar uma carga de 100mA. Uma bateria pequena de 9V não aguenta operação contínua. Ambos os diodos emissores de infra vermelhos devem de ser apontados para o diodo receptor. Quanto maior a distância mais bem alinhados devem de estar os diodos com o receptor. Sempre que o emissor irradia na direcção do receptor o led do receptor acende e o relé abre. O uso de lentes de focagem óptica pode aumentar consideravelmente o alcance da barreira. É o receptor exposto a raios de sol muito fortes, aconselhamos que o IR diodo de recepção "IF" seja protegido com um tubo contra luz difusa nos lados e na parte de trás. O orifício do tubozinho deve então estar ajustado em direcção ao emissor. O tubozinho deve ser na parte interior preto mate.

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(E) Barrera de luz con rayo de luz infrarrojo invisible. (Completo con emisor y receptor). Tensiones de servicio: emisor 9V, receptor 12V. Relé 1 x conector máx. 3A. Ideal para sistemas de alarma, fotos automáticos de animales, telemando para la puerta del garaje etc. ¡Con filtro infrarrojo instalado para el funcionamiento durante el día!

(F) Barrière optique avec rayon infra-rouge invisible. Complet avec émetteur et récepteur. Alimentation: émetteur 9V, récepteur 12V. Relais 1 x marche max 3A. Idéal pour systèmes d'alarme, photos automatiques d'animaux, commande à distance de portes de garages, etc. Avec filtre infra-rouge incorporé pour fonctionnement de jour!

(FIN) Valoveräjä näkymättömällä infrapuna-valosteella. Täydellinen lähettiminen ja vastaanottiminen! Käyttäjännitteet: lähtin 9V, vastaanotin 12V, relä 1 x kytk. maks. 3A. Ihanteellinen hälytyslaitteisiin, automaattiseen eläinkuvaukseen, autotallinoven etäisäjohtukseen ym. Sisäänrakennettu infrapunasuodatin päivänvaloa varten.

(NL) Lichtbarrière / -afstandsbediening met onzichtbare infraroodlichtstraal. Compleet met zender en ontvanger! Bedrijfsspanningen: Zender 9V, ontvanger 12V. Relais 1 x maak. max. 3A. Ideaal voor alarminstallaties, automatische dierenfoto's, garagedeuraafstandsbediening enz. Met ingebouwd infraroodfilter voor bedrijf bij daglicht!

(P) Barreira de luz infravermelha invisível. Receptor e emissor incluídos. Tensão de funcionamento: emissor 9V, receptor 12V relé de 1 x conector 3A. Ideal para sistemas de alarme, controle de animais, controle remoto de portas de garagem, etc. Com filtro de infravermelhos para funcionamento com luz do dia.

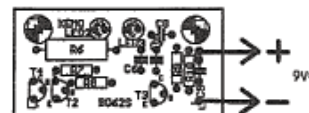
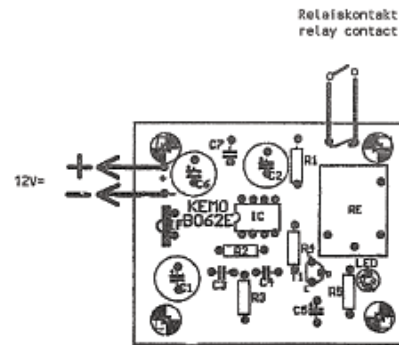
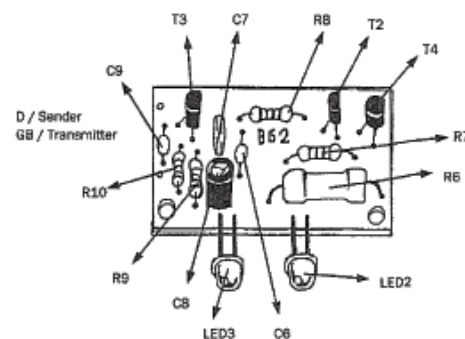
(GR)

ΤΗΛΕΔΙΔΡΟΜΗΤΗΣ ΥΠΕΡΥΦΘΩΝ 18m ΚΑΙ ΑΝΩ

Λειτουργεί με χωράτη δέσμη υπερυφθων ακτινων. Πληρης αυτοματισμος με πομπο και δεκτη. Μπορει με δυο φωτοκυτταρα να φτασει και τα 30 m. Χρησιμο για ασφαλιση προσωπικων αντικειμενων, αυτοματο αναμα φωτων, αυτοματος φωτογραφιες ζων, συναγερμος, γκαραζοπορτες κ.λ.π. Τιση πομπου 9 V και δεκτη 12 V. Ρελε επασης 3A.



Passende Gehäuse /
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A-2 Data Card NI6008

The National Instruments USB-6008 provides basic data acquisition functionality for applications such as simple data logging, portable measurements, and academic lab experiments. It is affordable for student use, but powerful enough for more sophisticated measurement applications. Use the NI USB-6008 with the included ready-to-run data logger software to begin taking basic measurements in minutes, or program it using LabVIEW or C and the included NI-DAQmx Base measurement services software for a custom measurement system. To supplement simulation, measurement, and automation theory courses with practical experiments, NI developed a USB-6008 Student Kit that includes a copy of the LabVIEW Student Edition. These kits are exclusively for students, giving them a powerful, low-cost, hands-on learning tool. Visit the NI academic products page for more details. For faster sampling, more accurate measurements, and higher channel count, consider the NI USB-6210 and NI USB-6211 high-performance USB data acquisition devices. Every USB data acquisition module includes a copy of NI LabVIEW SignalExpress LE so you can quickly acquire, analyze and present data without programming. In addition to LabVIEW SignalExpress, USB data acquisition devices are compatible with the following versions (or later) of NI application software: LabVIEW 7.x, LabWindows/CVI 7.x, or Measurement Studio 7.x. USB data acquisition modules are also compatible with Visual Studio .NET, C/C++, and Visual Basic 6. The next few pages will contain the data sheet.

A-3 Data Fitting Tables

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