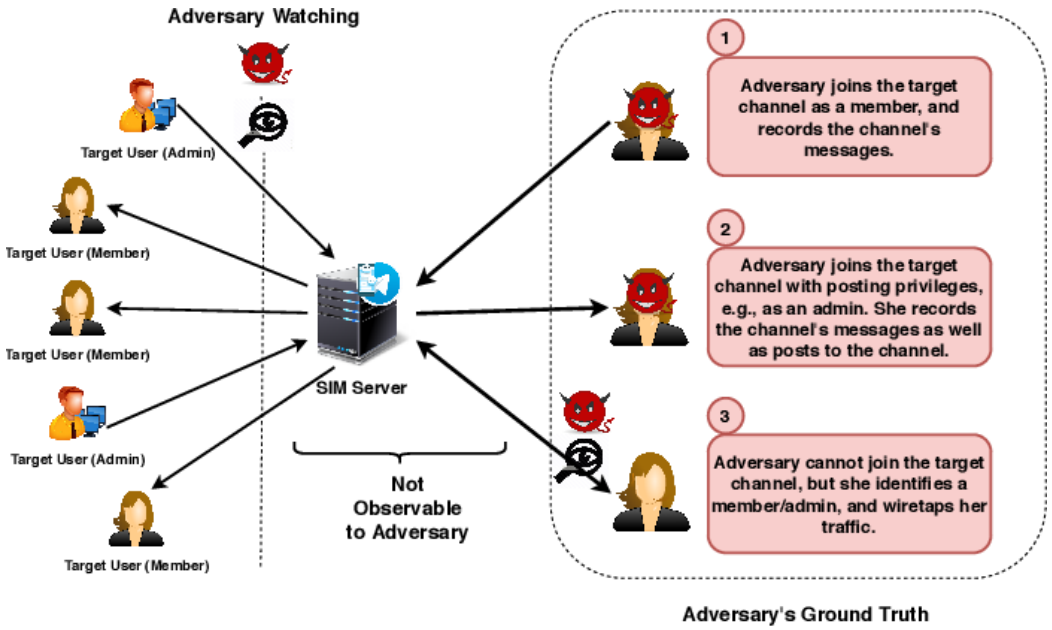
Practical Traffic Analysis Attacks on Secure Messaging Applications



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Dry Part

The attacker obtains the ground truth about the traffic of the target IM channel in one of three ways: Joining an open channel: If the target IM channel is an open or public channel, the attacker can join the channel as On can be actively active in the channel, record the messages sent along with their metadata, such as the time and size of the messages. This information provides real information about the traffic patterns of the channel.
Sending messages to the channel: A rule that in cases where the attacker has already joined the target's instant messaging channel sent the message to post messages. This can happen if the channel is a closed group that allows any member to post messages or if an admin role has been accepted for the channel. By recording the incoming and outgoing messages, the attacker can capture the traffic patterns of the channel including its messages with different traffic patterns.
Member/admin eavesdropping: If the attacker is unable to join the target channel as a member or administrator, he can still obtain ground truth information by detecting the IP address of one of the channel's members or administrators. The attacker then eavesdrops on the identified member/manager's network traffic, intercepting their encrypted communications. By recording the traffic patterns of the detected member/manager, the attacker can use this information as ground truth to match the traffic patterns of other intercepted flows.
In summary, the attacker obtains the ground truth about the traffic of the instant messaging channel by actively participating in the channel, intercepting the traffic of administrators/members, or by listening to the network traffic of specific people associated with the channel.
Furthermore the attacker eavesdrops on the network traffic of IM users to identify the IP addresses of the members/administrators of the targeted IM channel. The specific methods mentioned include: Eavesdropping on Internet Service Providers (ISPs) or IXPs: The attacker can control or gain access to network infrastructure, such as Internet Service Providers (ISPs) or Internet Exchange Points (IXPs). By eavesdropping on the network traffic passing through these control points, the attacker can intercept and monitor the encrypted network traffic of instant messaging users.
Eavesdropping on certain people: In some cases, the attacker may target certain people, such as suspected activists. After obtaining a wiretapping warrant or gaining unauthorized access, the attacker intercepts the network traffic of these individuals to record their traffic patterns.
It is worth noting that eavesdropping on network traffic usually involves capturing and analyzing the data packets transmitted over the network. This can be done by various means, such as deploying network monitoring devices, using special software or hardware tools, or compromising the network infrastructure or endpoints to gain access to traffic. The exact details of how the attacker communicates with network traffic can depend on the technological capabilities and resources available to the attacker.It can be seen in the study that Table II provides an overview of the distribution of the different types of messages in the collected instant message traffic. The table shows statistics such as the count, volume (in MB), size range, and average size for each message type, including text, image, video, file, and audio messages. From the table, we can observe the relative proportions of different message types in the instant messaging traffic database. For example, text messages account for about 29.4% of the total, followed by images (48%), videos (15.4%), files (2.1%) and audio messages (5.1%).
In addition, the table provides insights into the size characteristics of different message types, such as their size range and average values.

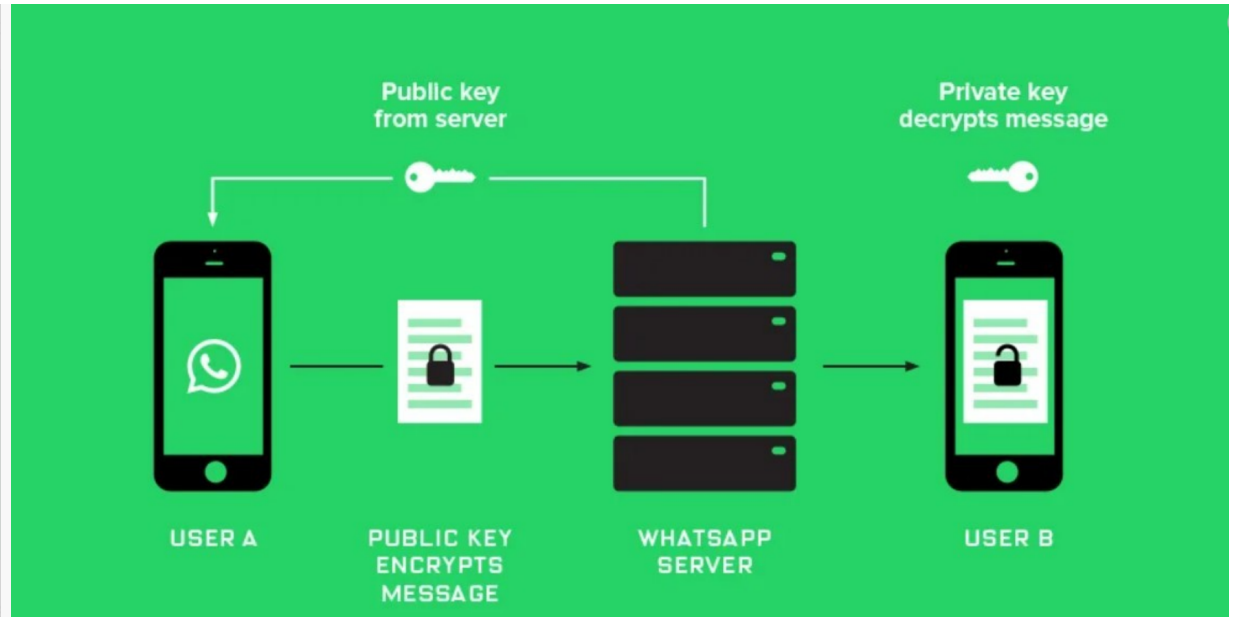
This data is essential for understanding the composition and characteristics of instant message communication, which informs us about building models and analyzing instant message traffic, as well as developing traffic analysis attacks.
In communication systems, each SIM event, such as sending an image, produces a bubble of MTU-sized packets in the cryptographic traffic. These packets have tiny delays between the packets and their size corresponds to the size of the MTU.
The bubbles represent SIM events, while scattered packets of small size represent the SIM protocol messages such as alert messages, manuals, updates, etc. To detect these bubbles and reveal the SIM events, the researchers use Inter-Packet Time Threshold (IPD), which is denoted as "tea".
Two packets with a time distance smaller than te will be considered to be part of the same bubble.
The te value is a hyperparameter term in the model, and its choice is discussed in the paper.
For each bubble detected using te, the enemy can reveal a SIM event.
The time of the arrival of the last packet in the bubble indicates the arrival time of the event, and the sum of all the sizes of the packets in the bubble gives the size of the event. In addition, two SIM messages sent with an inter-message distance (IMD) less than te will be considered part of the same event.
The adversary combines events that are closer than te when running a grow on the target channel, this approach allows the adversary to detect SIM events by looking for bubbles of MTU-sized packets, even though the contents of the packets remain encrypted and inaccessible.

Beginning of research:

In this part of the project, we tried how to see in the most abstract way the relationship of our computer with the WhatsApp server, including all communications that call the application.

We discovered that it's not that simple, as we know, WhatsApp is an end-to-end encrypted application From Wikipedia:

In November 2014, Open Whisper Systems announced a collaboration with WhatsApp to establish an infrastructure for end-to-end encryption with the Signal protocol. After the establishment of the infrastructure in April 2015, the WhatsApp company stated that all forms of communication of the application are strongly encrypted (WhatsApp conversations are encrypted using the SRTP protocol) in such a way that, according to the company's claim, no one, including Facebook itself, which owns WhatsApp, and not even the NSA or any other government organization can get access to any Misron content or conversation.In October 2015, WhatsApp began to transfer all the messages of the

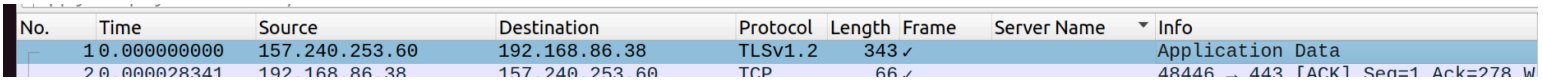


application's users to Google servers using Google Drive by default. This step raised many doubts regarding the company's statement that no third party will be able to read the users' messages, because all the user's messages are uploaded to Google's servers without encryption on the part of WhatsApp, but only if there is encryption by the server.

Starting in April 2016, WhatsApp began to encrypt all users' messages, photos, videos, voice messages, documents and conversations, using end-to-end encryption. And she claimed that: "When you send a message, the only person who can read it is the person or group you are sending the message to. No one will be able to read your message: not cyber criminals, not hackers, not oppressive regimes, not even us."
photo: https://www.urtech.ca/2020/07/how-to-verify-that-whatsapp-messages-are-encrypted/

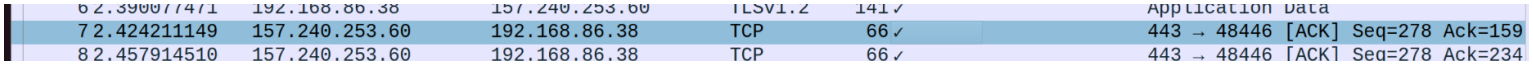
As part of our attempts, we were not able to record with wireshark packets that pass through our network when we enter the application from the mobile, all our attempts within the framework of our knowledge, failed to understand how it is possible to identify any activity from the mobile. Therefore, we focused on investigating the packets that are transferred between our computer (which is connected via the browser to the application) to the WhatsApp server. First, to understand the process, we recorded a conversation between two people on WhatsApp so that we are connected to the application through our computer, and the other party is not in our vicinity. In this conversation, text messages, voice messages, photos, videos and files were transferred.
In addition, we tried to understand which protocols the application uses, and we found that there are several protocols that WhatsApp uses as part of its services:
WhatsApp uses a combination of protocols to provide secure and efficient messaging services. These protocols ensure confidentiality and efficiency.

1.TLS: Encrypts the connection between the user's device and the WhatsApp servers.
This ensures privacy and prevents unauthorized access to data during transmission.



No.	Time	Source	Destination	Protocol	Length	Frame	Server Name	Info
1	0.000000000	157.240.253.60	192.168.86.38	TLSv1.2	343	✓		Application Data
2	0.000028341	192.168.86.38	157.240.253.60	TCP	66	✓		48446 → 443 [ACK] Seq=1 Ack=278 W

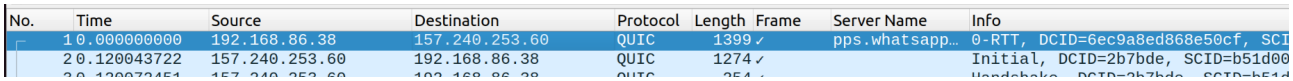
2.TCP: provides reliable delivery, ensuring that messages are received in the correct order without data loss, especially in text-based communication.



6	2.390077471	192.168.86.38	157.240.253.60	TLSv1.2	141	✓		Application Data
7	2.424211149	157.240.253.60	192.168.86.38	TCP	66	✓		443 → 48446 [ACK] Seq=278 Ack=159
8	2.457914510	157.240.253.60	192.168.86.38	TCP	66	✓		443 → 48446 [ACK] Seq=278 Ack=234

3.UDP: Faster data transfer, used for real-time communication, such as voice calls and maybe some multimedia sharing.
Improves user experience by reducing delays in time-sensitive interactions.

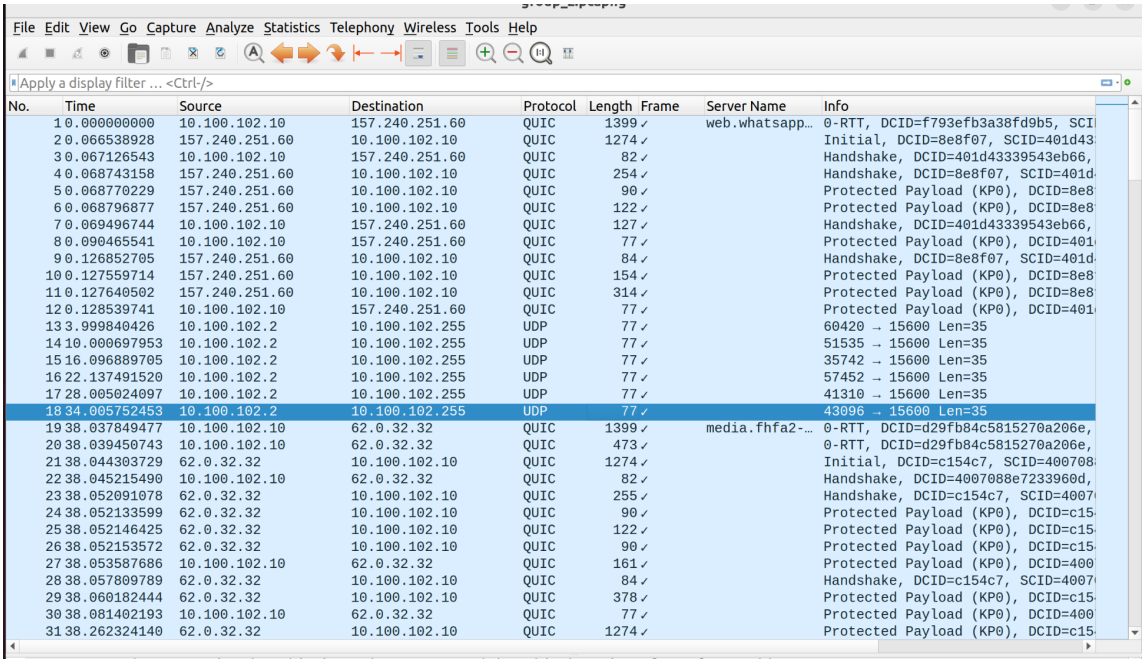
4.QUIC: Optimizes data transfer over unreliable networks, combining features of TCP and UDP.Especially messages and voice calls.



No.	Time	Source	Destination	Protocol	Length	Frame	Server Name	Info
1	0.000000000	192.168.86.38	157.240.253.60	QUIC	1399	✓	pps.whatsapp…	0-RTT, DCID=6ec9a8ed868e50cf, SCI
2	0.120043722	157.240.253.60	192.168.86.38	QUIC	1274	✓		Initial, DCID=2b7bde, SCID=b51d00

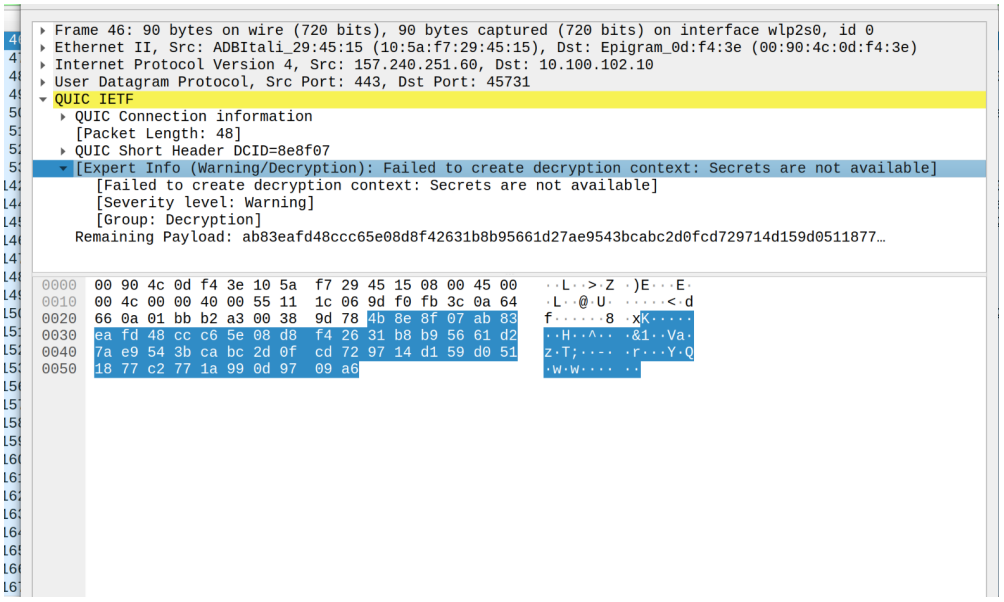
So how did we choose the packages for the groups we documented? We relied on these protocols, all the packets that were linked to the WhatsApp server, and arrived from our computer or to our computer or via port 443.
We cleaned all the traffic with other devices that are connected to our network.

And back to the conversation we recorded-
In Wireshark you can see the packages relevant to the call as follows:
In the above recording you can see many packets that pass through different protocols from our computer (10.100.102.10) to the server 157.240.251.60 which is the server of WHATAPP WEB.



No.	Time	Source	Destination	Protocol	Length	Frame	Server Name	Info
1	0.000000000	10.100.102.10	157.240.251.60	QUIC	1399	✓	web.whatsapp…	0-RTT, DCID=f793efb3a38fd9b5, SCI
2	0.066538928	157.240.251.60	10.100.102.10	QUIC	1274	✓		Initial, DCID=8e8f07, SCID=401d43
3	0.067126543	10.100.102.10	157.240.251.60	QUIC	82	✓		Handshake, DCID=401d43339543eb66,
4	0.068743158	157.240.251.60	10.100.102.10	QUIC	254	✓		Handshake, DCID=8e8f07, SCID=401d
5	0.068770229	157.240.251.60	10.100.102.10	QUIC	90	✓		Protected Payload (KP0), DCID=8e8
6	0.068796877	157.240.251.60	10.100.102.10	QUIC	122	✓		Protected Payload (KP0), DCID=8e8
7	0.069496744	10.100.102.10	157.240.251.60	QUIC	127	✓		Handshake, DCID=401d43339543eb66,
8	0.090465541	10.100.102.10	157.240.251.60	QUIC	77	✓		Protected Payload (KP0), DCID=401
9	0.126852705	157.240.251.60	10.100.102.10	QUIC	84	✓		Handshake, DCID=8e8f07, SCID=401d
10	0.127559714	157.240.251.60	10.100.102.10	QUIC	154	✓		Protected Payload (KP0), DCID=8e8
11	0.127640502	157.240.251.60	10.100.102.10	QUIC	314	✓		Protected Payload (KP0), DCID=8e8
12	0.128539741	10.100.102.10	157.240.251.60	QUIC	77	✓		Protected Payload (KP0), DCID=401
13	3.999840426	10.100.102.2	10.100.102.255	UDP	77	✓		60420 → 15600 Len=35
14	10.000697953	10.100.102.2	10.100.102.255	UDP	77	✓		51535 → 15600 Len=35
15	16.096889705	10.100.102.2	10.100.102.255	UDP	77	✓		35742 → 15600 Len=35
16	22.137491520	10.100.102.2	10.100.102.255	UDP	77	✓		57452 → 15600 Len=35
17	28.005024097	10.100.102.2	10.100.102.255	UDP	77	✓		41310 → 15600 Len=35
18	34.005752453	10.100.102.2	10.100.102.255	UDP	77	✓		43096 → 15600 Len=35
19	38.037849477	10.100.102.10	62.0.32.32	QUIC	1399	✓	media.fhfa2-…	0-RTT, DCID=d29fb84c5815270a206e,
20	38.039450743	10.100.102.10	62.0.32.32	QUIC	473	✓		0-RTT, DCID=d29fb84c5815270a206e,
21	38.044303729	62.0.32.32	10.100.102.10	QUIC	1274	✓		Initial, DCID=c154c7, SCID=400708
22	38.045215490	10.100.102.10	62.0.32.32	QUIC	82	✓		Handshake, DCID=4007088e7233960d,
23	38.052091078	62.0.32.32	10.100.102.10	QUIC	255	✓		Handshake, DCID=c154c7, SCID=4007
24	38.052133599	62.0.32.32	10.100.102.10	QUIC	90	✓		Protected Payload (KP0), DCID=c15
25	38.052146425	62.0.32.32	10.100.102.10	QUIC	122	✓		Protected Payload (KP0), DCID=c15
26	38.052153572	62.0.32.32	10.100.102.10	QUIC	90	✓		Protected Payload (KP0), DCID=c15
27	38.053587686	10.100.102.10	62.0.32.32	QUIC	161	✓		Protected Payload (KP0), DCID=400
28	38.057809789	62.0.32.32	10.100.102.10	QUIC	84	✓		Handshake, DCID=c154c7, SCID=4007
29	38.060182444	62.0.32.32	10.100.102.10	QUIC	378	✓		Protected Payload (KP0), DCID=c15
30	38.081402193	10.100.102.10	62.0.32.32	QUIC	77	✓		Protected Payload (KP0), DCID=400
31	38.262324140	62.0.32.32	10.100.102.10	QUIC	1274	✓		Protected Payload (KP0), DCID=c15

All the packets that are transmitted by the QUIC protocol, probably in the picture, are the packets that transmit the information of the WhatsApp conversation between two people. You can see that all the information is encrypted and cannot be accessed.



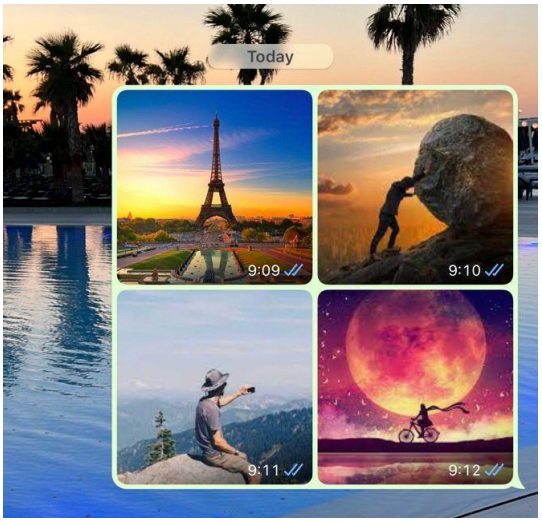
Additionally, we created the **messages_over_time.py program**
which simply shows us the size of the packets sent on the network throughout the call,
You can see the sharp jumps when it comes to sending photos/files or videos and voice messages.
The significantly smaller packets can be part of the whole big message or packets that are sent as part of the protocol (handshakes, etc.).

In our project we focused on the Event-Based Detector attack algorithm according to the article.
Therefore
In order to understand the subject we have to investigate, we continued to document relatively simple WhatsApp groups (a group of a few people with a distinct character such as sending pictures only), in order to understand how to draw conclusions and reach good results, from there we continued to more complex groups in our project, we start by studying the simple things and drawing the conclusions from them in order to continue to the more complex parts.

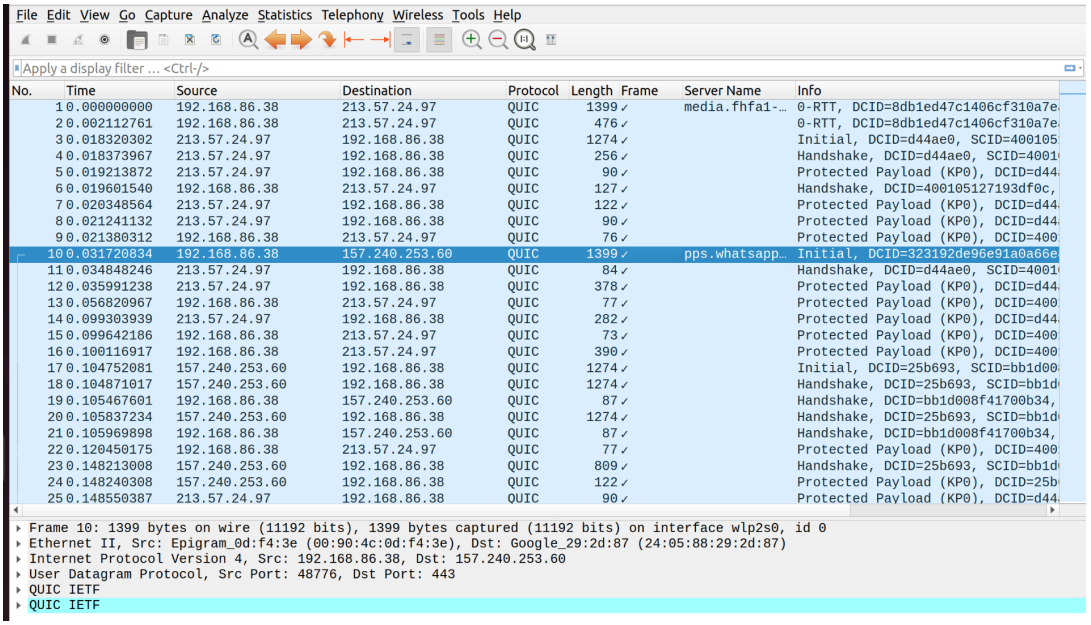
Event-Based Detector

Group number 1:

This group is characterized by sending pictures, a group in which the manager sends pictures, that is, the transfer of the content is through pictures only through the manager to the participants.
We carried out an event where every minute a photo was sent to the group from the manager (who is connected to whatsapp web).



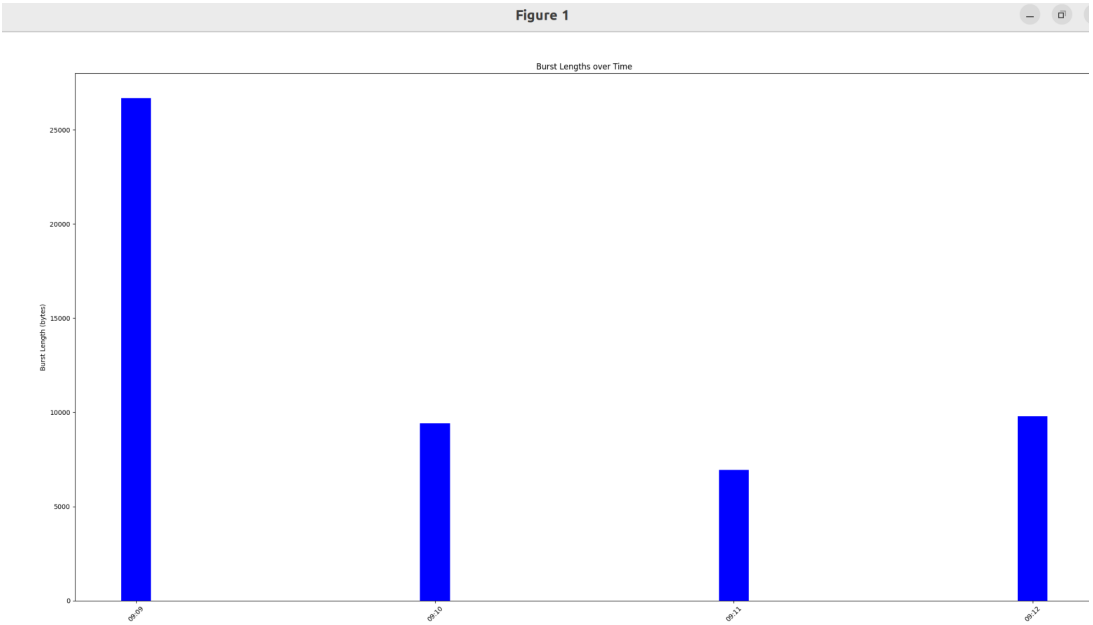
Similarly, as we saw earlier, if we filter all the packets that pass through our network and leave those that use the QUIC protocol, the wireshark recording will look like this



In the recording we record an intriguing thing:
It seems that in addition to the connection between our computer (192.168.86.38) and the WhatsApp server (157.240.253.60)
There is another connection between our computer and the address (213.57.24.97), after checking we discovered that it is a HOT server in Israel.
We assume that sending the photos from our computer to the WhatsApp server is done as follows:

Our computer (the client), starts the process by accessing WhatsApp Web. This involves opening a web browser and visiting the WhatsApp web interface.
WhatsApp may use content delivery networks (CDNs) to optimize the delivery of media, such as images. These CDNs consist of servers distributed in different locations around the world. It is possible that the server in question is the server we found in the recording. And when we send an image, it is routed through this server.

event detector graph:
In order to carry out the attack algorithm we will use the program event_extraction.py which creates the event separation for us (a detailed explanation can be found in detail on github).
We will get the following graph: th 0.00001

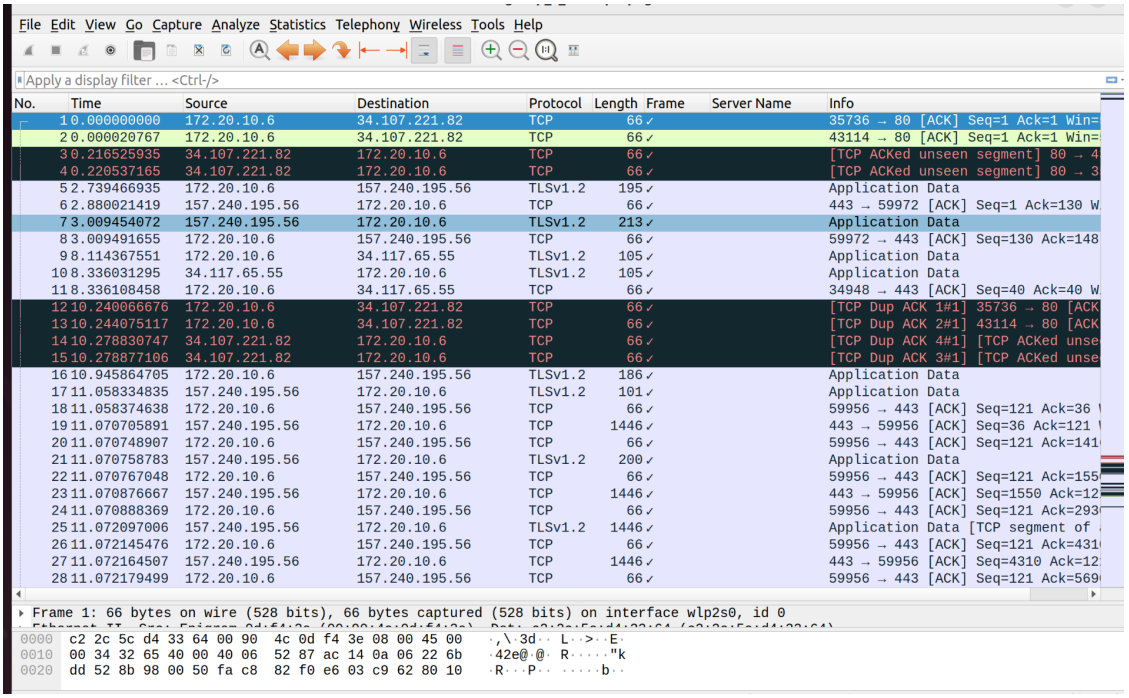


Which appropriately shows us the sending of the 4 photos every minute in the group as a separate event.
It can be concluded that the nature of the group is such that relatively large files are sent (more than 25000 bytes per minute) at consecutive and odd times, so it may also be possible to conclude that it is one person who is sending the information.
But we will note that the size of the images here does not accurately describe their original size, we tried to understand why this is so and came to the following conclusions:
When we send pictures through WhatsApp, the application compresses them before sending them over the network. The compression is done to reduce the size of the image, since smaller images require less bandwidth and storage.
The disparity between file sizes can be attributed to several factors, including image format conversion, metadata abstraction, and additional compression applied by WhatsApp.
1. Image format conversion: WhatsApp may convert the images to a more efficient format (eg, WEBP) which will result in smaller file sizes.
2.Remove metadata: WhatsApp may remove some metadata or non-essential information from the images, further reducing the file size. Therefore we see that the size of the packages that are sent is relatively small.
In summary, the difference in file sizes is due to WhatsApp's image compression and optimization techniques, which reduce file sizes for efficient network transfer and user experience.

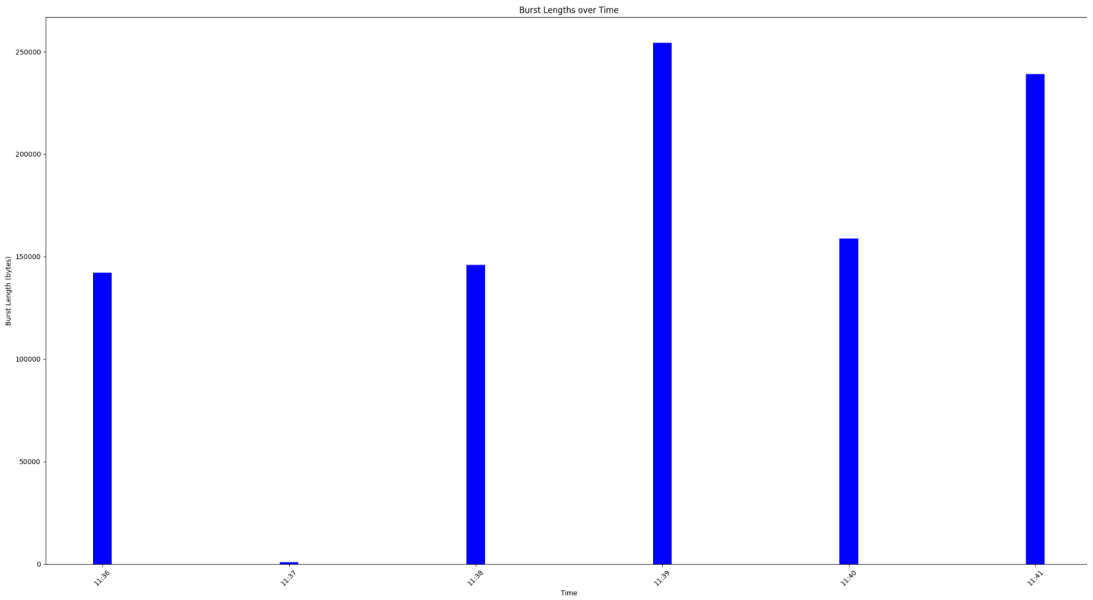
Group number 2:

A group where 5 videos were sent to participants every minute.

wireshark:



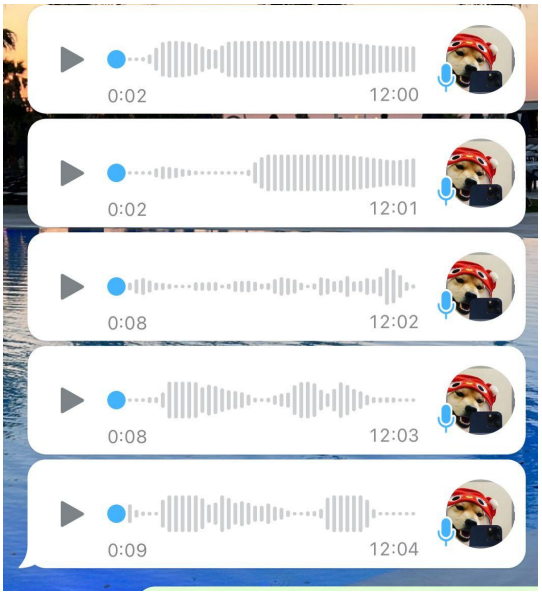
event detector graph:



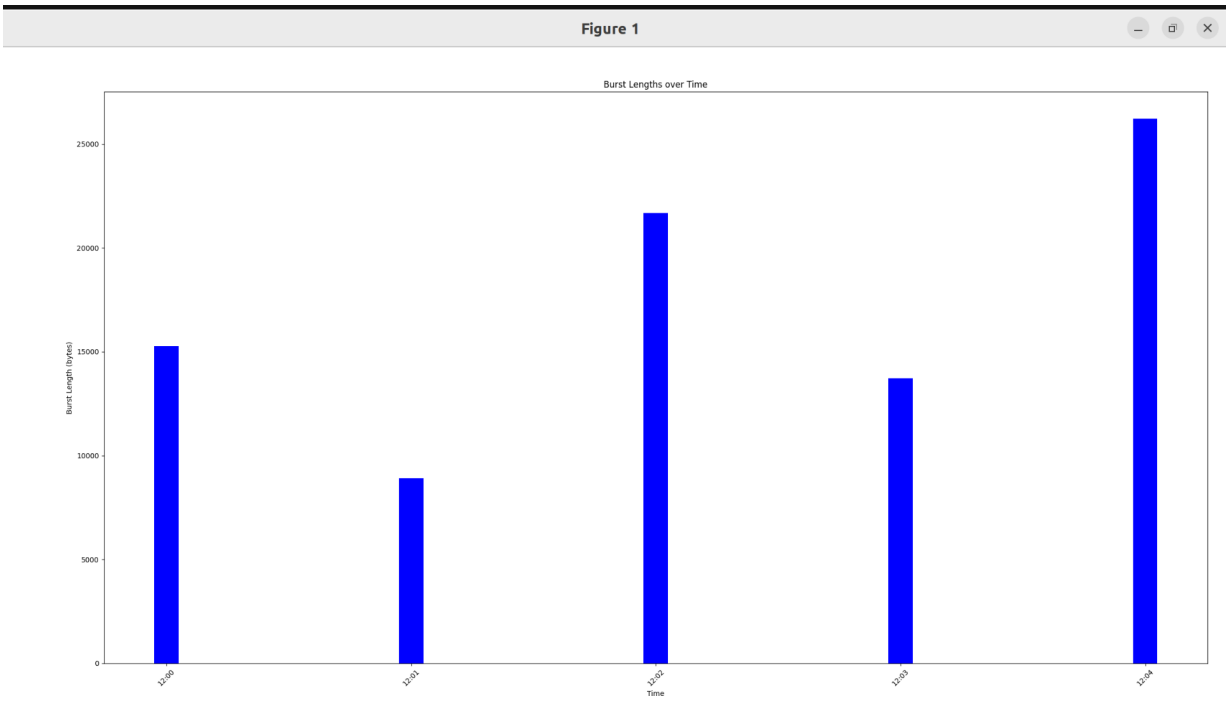
With th=0.1 we were able to identify the sizes and export the corresponding events of sending a video every minute, in addition each event corresponds to the size of the videos and at 11:39 we sent a longer video and this is also seen from the graph.
In addition, we had a small break between sending the messages at the beginning and you can see in the 37th minute that there is minimal sending of packages.

Group number 3:

In this group we received voice messages every minute from a participant in the group



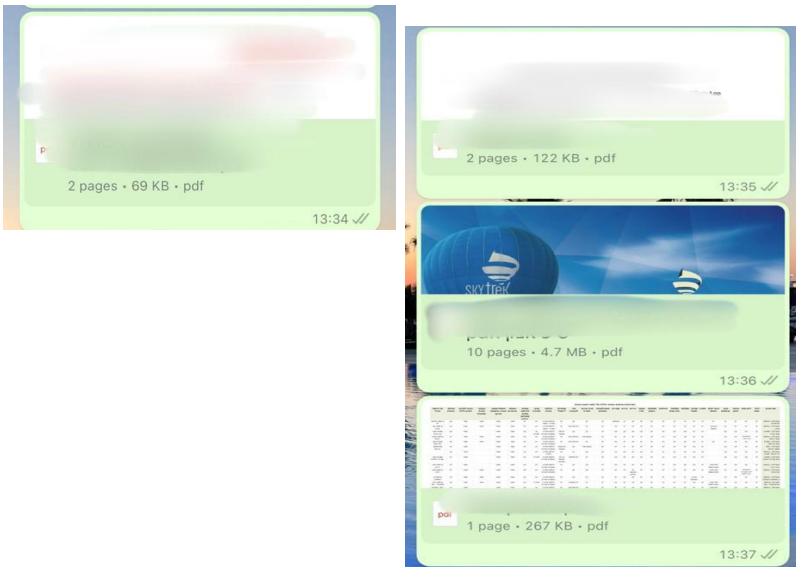
Event detection graph:



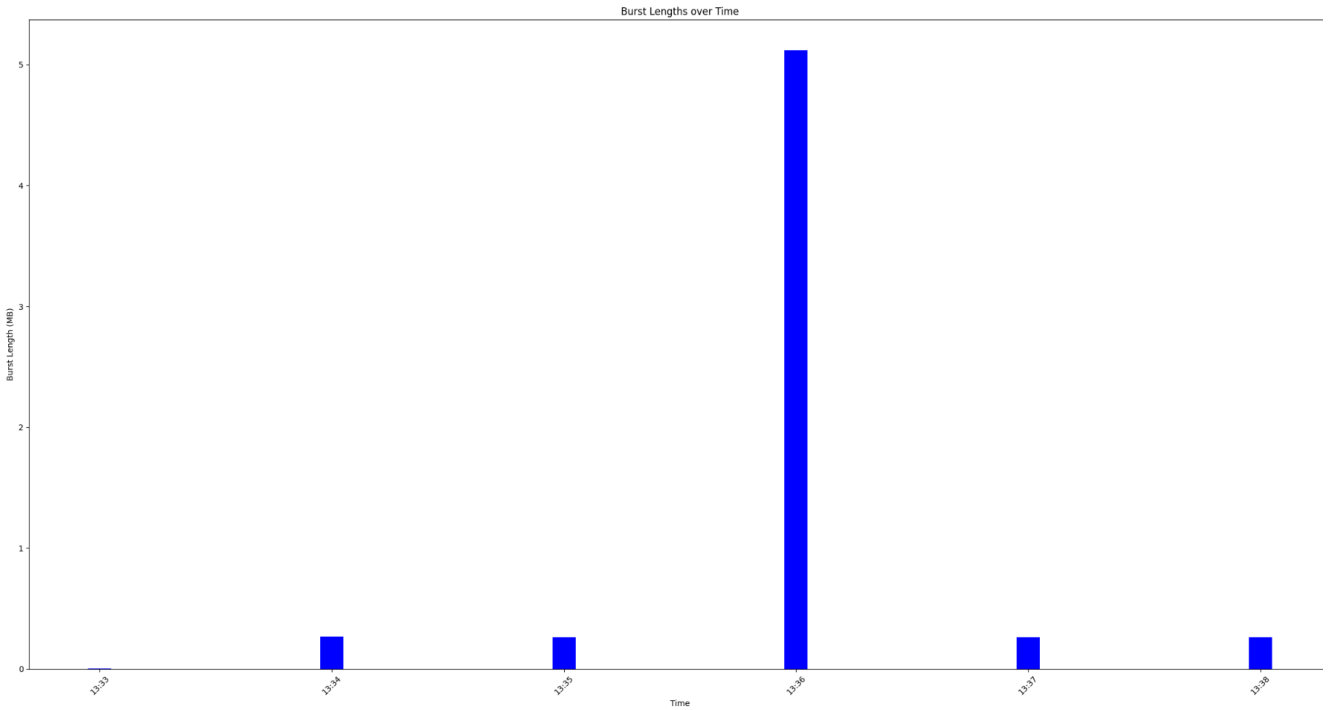
According to th=0.1 we see that even though there are messages that the recording time is the same but there is still a difference in the sizes of the events, therefore we can assume that the size not only depends on the time but also on the "voice sequence" which affects the size of the packet.

Group number 4:

In this group we sent different PDF files of different sizes every minute.



Event detection graph:



Since there is a 5MB file, we created another program that will show us the information in MB. You can clearly see the sending of the largest file in relation to all other messages. In addition at 13:38

we see that another message is received that is not related to the group (from another group) and we see how this hinders us from analyzing the information from the group we are investigating.

Group number 5:

A group where the manager (we) transfer photos and files.

While in the open window my Gmail receives emails. In the group the conversation looks like this:

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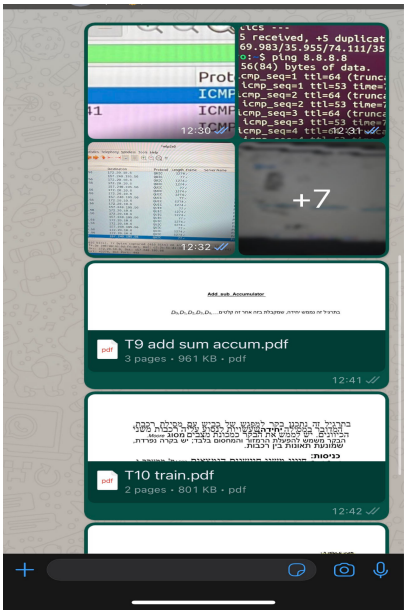


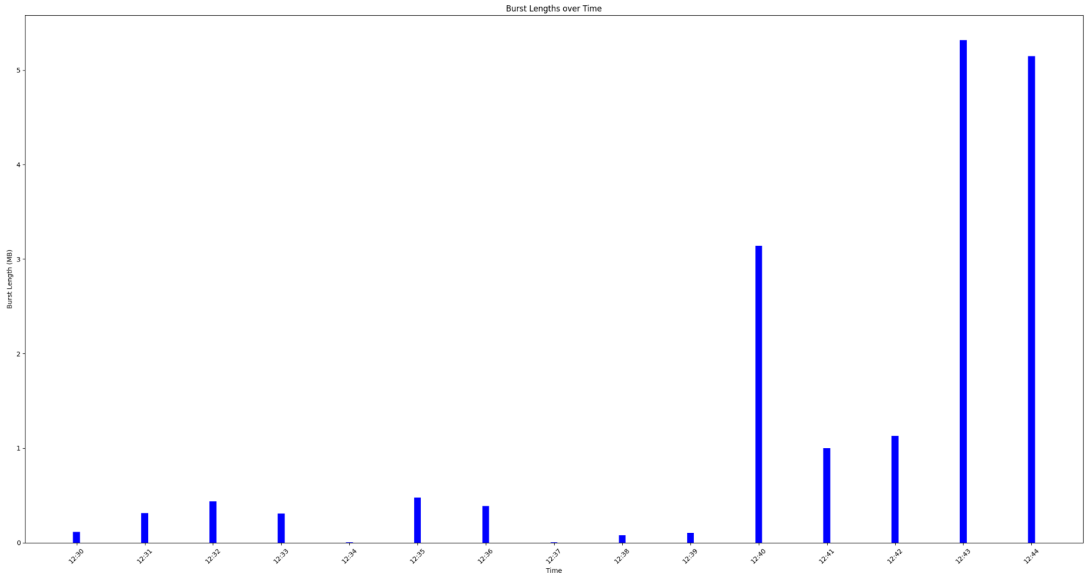
In this group, photos and files were sent as follows:

Images were sent one minute apart, then files were sent one after the other with one minute apart.

While sending these messages, WhatsApp was open to "background noise", email (gmail) was open while receiving the files, in addition, text messages from another group were also received.

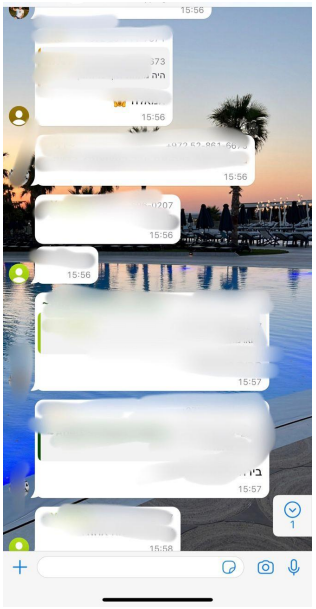
So here we simulate a situation where the attacker listens to a certain group but the attacked has noise not only from the application but also from the network.

event detector graph:

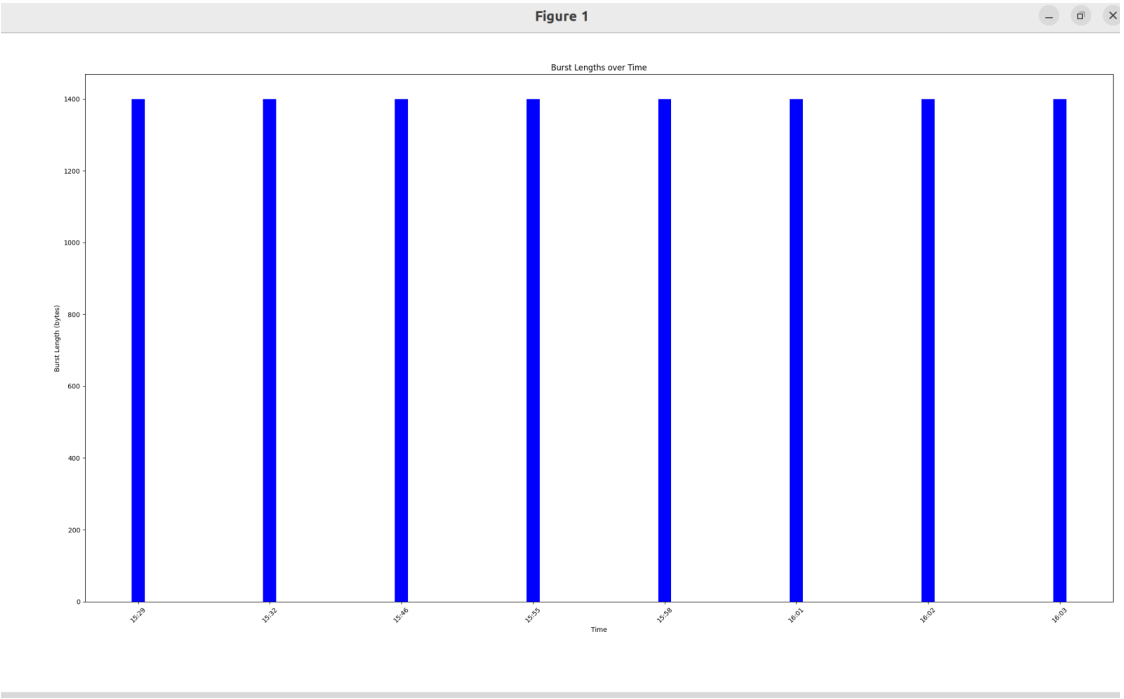


The graph shows us the sending of images every minute and in fact you can see that on average the attacker can conclude that the messages sent every minute on average are more or less the same in terms of weight, and then there is a big jump in the graph at 12:40 so the attacker can understand that this is a suspicious jump, that is A message with greater weight and understand that it is a different file type and not an image
In this way, the attacker actually gets an illustration of what type of messages are in the group and thus understands what its "character" is, is it the desired group and can also conclude that due to the unusual size it is a disturbance.

Group number 6:
We recorded a group of the degree course after an exam in the course



event detector graph:



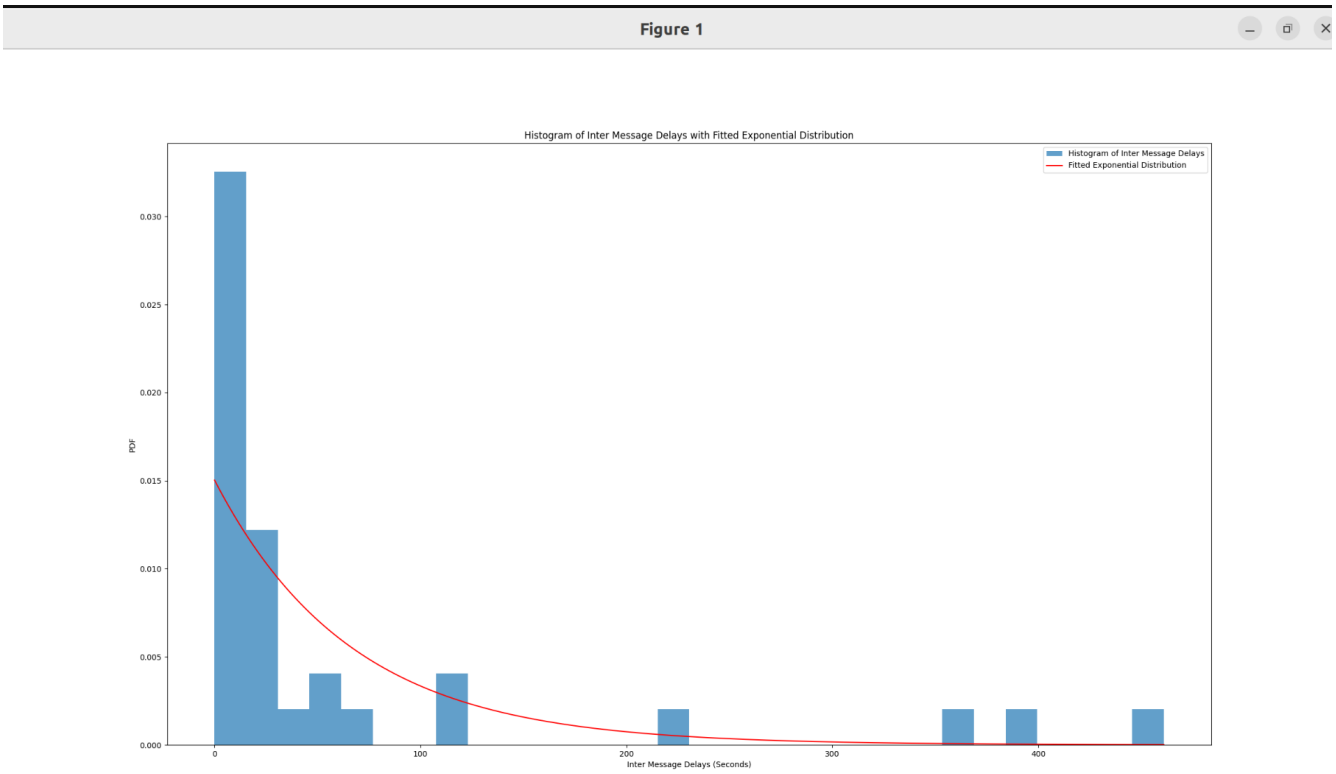
Here you see again that there is a kind of "pace" in the messages and every minute several people send a message and the events are still very small, so it can be understood that these are text messages in a group of messages with many participants in a crowded conversation. (thr=0.000001)

Histogram graph:

The graph shows us the density of the messages, at first you see the blue columns tall and thick and then they swell, this shows that every minute the delay between the messages decreases, which tells us that the group is active.

Here we see how the dwell time decreases as the conversation time continues (more people join the conversation and become part of it after leaving the exam.)

It is important to note that the pdf graph was created by taking the chat from an application, therefore we did not upload these files in order to maintain the privacy of the participants.



Vertical Columns (Blue Bars): The blue bars are like columns that show how often different delays between messages happen. The short columns are for quick messages, and the tall columns are for slightly longer delays. Each column represents a range of delay times.

Red Curved Line (On Top of Columns): The red curved line is a special line that helps us understand the pattern of these delays. It's like a magical line that tries to fit itself over the columns in a way that makes sense. It shows us how likely certain delay times are.

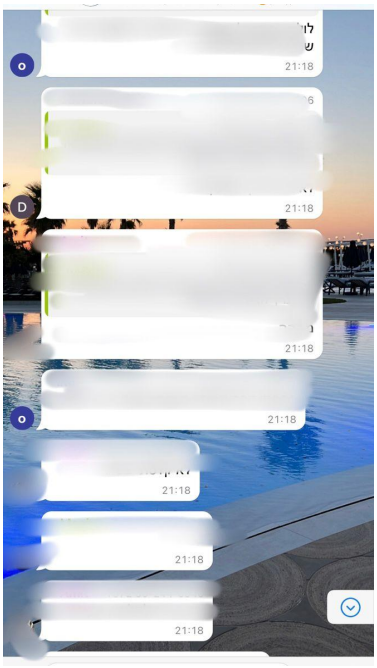
Height of Bars and Curve: The taller the blue bars or the red curve at a certain point, the more often those kinds of delays happen. So, if a bar is really tall or the curve is high at the beginning, it means quick messages are really common.

Slanting Down Red Curve: The red curve starts high on the left and gently slopes down to the right. This means that really quick message delays are very common, but as the delay time gets longer, it

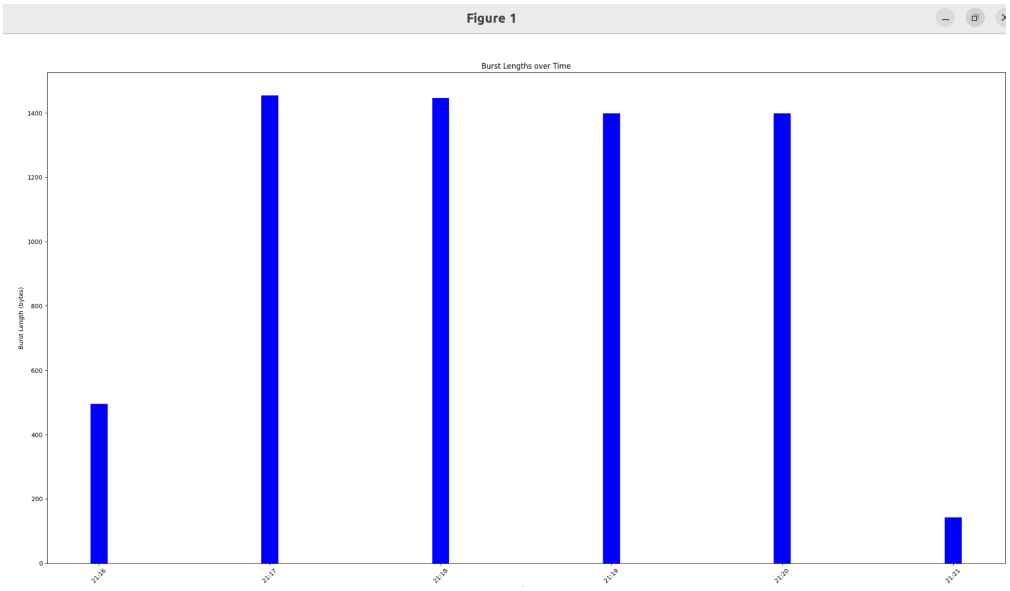
becomes less common. It's like saying, "Most of the time, messages are sent quickly, but longer delays happen less often.

Group number 7:

Another (another) group that we recorded after a test and you can notice the relatively noisy nature of messages that are sent together per minute!

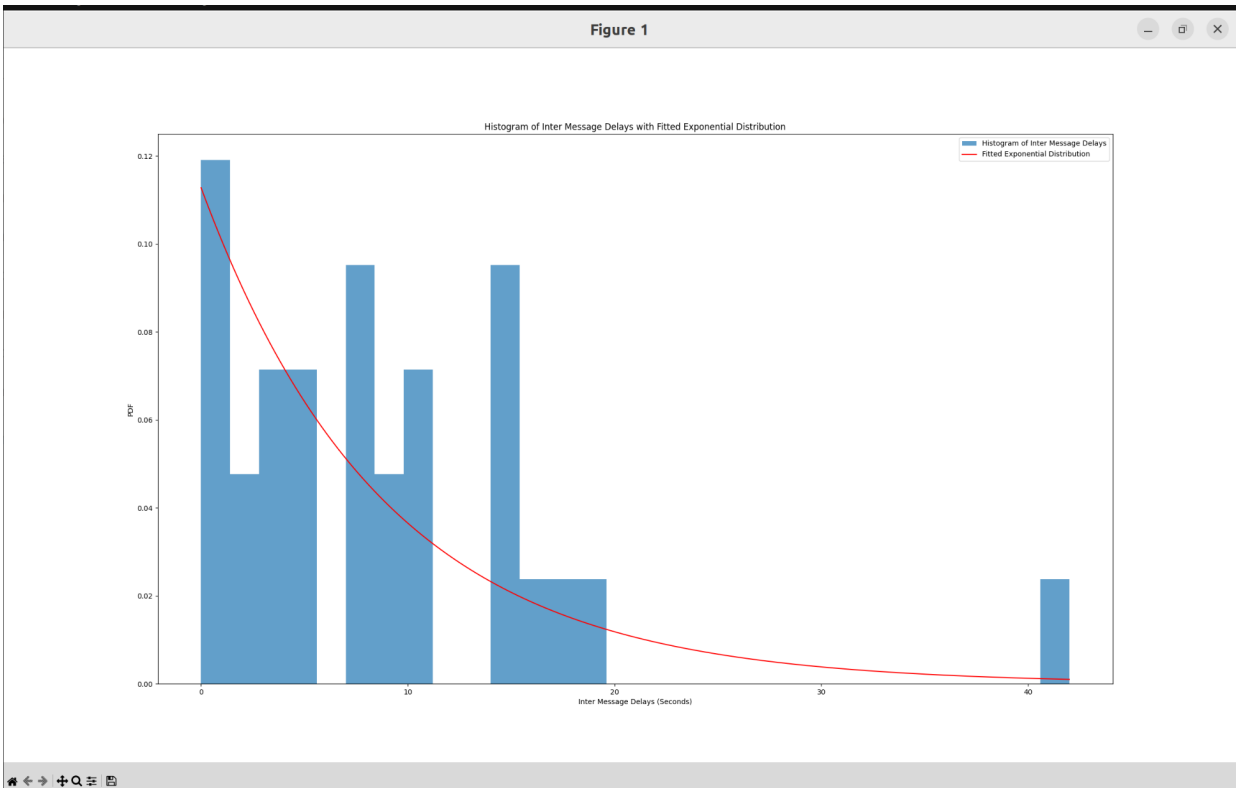


event detector graph:



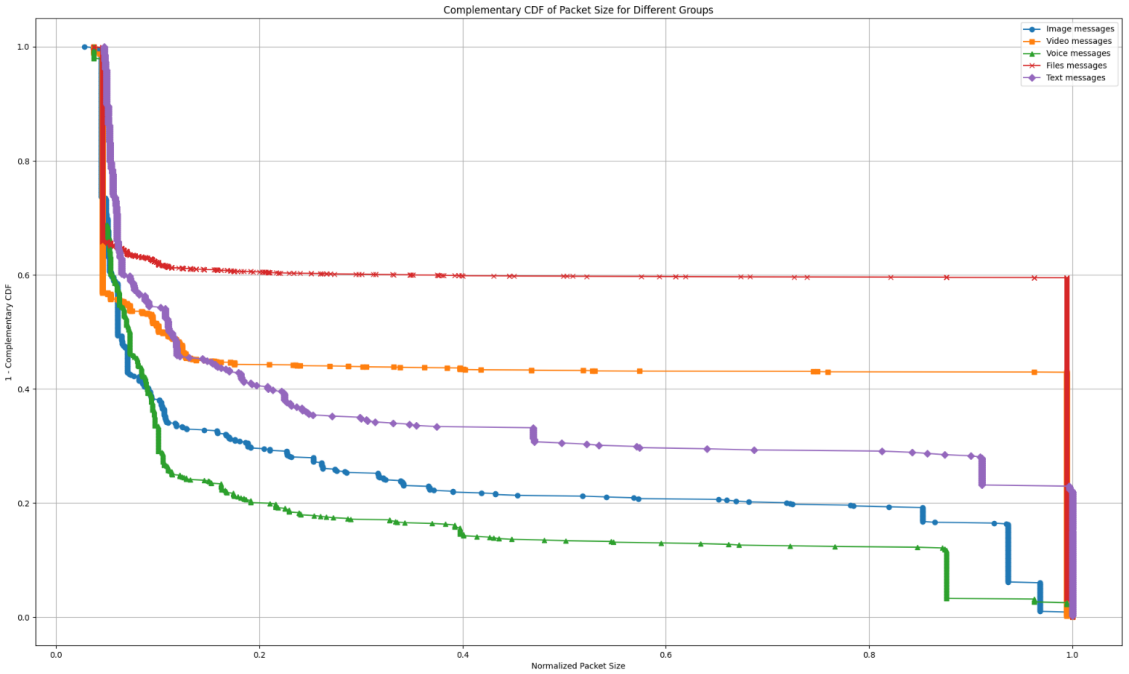
You can see that every minute there is an event but it is relatively small, considering that a text message is between 200 and 100 bytes in size, you can see that a relatively large sequence of messages is sent here every minute (text messages).

Histogram graph:



It can be seen that the shorter dwell time comes more frequently and indeed the group is very "noisy" as you can notice.

CDFF:



By groups number 1,2,3,4,6 we created the CCDF graph.The graph shows the complementary cumulative distribution function (CCDF) of the packet sizes normalized to four different groups.Each group represents a different type of message transfer (text, video, images, etc.). The X-axis represents the normalized packet size, ranging from 0 to 1, where 1 corresponds to the maximum size recorded in the group. The Y-axis represents the inverse function of the inverse density distribution function (1 - CCDF), which essentially shows the probability that the message size will be greater than a certain threshold. Or in simple words, for each group each package is normalized by size and we can see from the graph what is the probability of seeing it in the group.

Summary and conclusions

In our analysis, we investigated the network traffic from WhatsApp messages in different groups. We made interesting observations and faced several challenges in deciphering the data.

Group number 1: images only
We noticed that sending pictures on WhatsApp led to significant size discrepancies between the original packet capture data and the file sizes displayed in the application.
WhatsApp's image compression and format conversion significantly reduced image sizes during transmission, making it difficult to accurately infer the original image size from the displayed information. This can make it difficult for the attacker to understand what the group in question is and identify their affiliation.

Group number 2: Videos
In this group, we had a clear and reliable pattern of messaging behavior. And the attacker could clearly identify that it is indeed the group of videos by the sizes the videos were sent if he can from the group.

Group number 3: recordings
In this group it is also possible to understand that these are recordings, if the enemy knew their length and time.

Group number 4: files
In this group, we saw that the size of the files is quite clearly visible on the graph, therefore, considering the file sizes and times, the group can be analyzed.

Group number 5: files and image This group had noise from another server and we saw that there was interference but it can still be seen that this does not significantly affect the sizes of the events.

Group number 6,7 Text messages: In text groups we were not able to export the size of a message because in messages there are many cases in reality that several messages are sent even in one minute. Therefore the graph is not accurate and it can still be understood that this is the nature of a group with relatively small sizes, compared to the other types of messages text messages are very small and therefore while sending messages the enemy can identify the nature of the group by small but continuous events. It can be concluded that the algorithms in the article do demonstrate the potential to discern group communication patterns Although challenges exist, this analysis provides important insights into the nature of different groups and can be a valuable tool for understanding the dynamics of WhatsApp groups.
As for the question of whether it is possible to understand whether it is possible to identify the groups in which the attacked participates when he communicates with several groups at the same time, it can be seen that this is relatively very complex. Even if the attacker participates in groups we participate in. There will be a very large "mixing" of messages, and it is not possible to analyze which group each

package belongs to. When the attacker listens to a single group, it is relatively easy to export the events and analyze them according to the nature of the messages and the sending times.
Another thing we investigated is why when we listened to the recordings of WhatsApp conversations we can see that sometimes the packets are seen as TCP QUIQ HTTP etc. The question is why it can appear differently each time and what can be learned from this?
The variation in the types of packets observed when intercepting and analyzing traffic on WhatsApp Web stems from the nature of the communication protocols used by the application and the structure of the transmitted data.
WhatsApp Web uses protocols in different data formats to facilitate communication between the client and the server.
When we checked the groups, we tried to do it during "quiet" times in order to get as clean a recording as possible and to be sure that these are indeed the packages related to the only WhatsApp groups in which we are active for a limited time. (whether we send messages or receive messages). When messages are sent simultaneously from several calls, the matter is more complex and it will not be possible to accurately identify which packages are related to which call.
More than that, we noticed that the attacker must also calculate and create a graph as real as possible with an appropriate threshold in order to get the nature of the events in the group. In addition, he must clean the packages that are bothering him.
That's why we think that in the end it takes time and investment and the attacker should be in the group in order not to "get lost" in all the information that passes through the attacked network.
When the attacker tries to coordinate a person's presence in multiple groups or channels, they face several challenges due to the nature of the WhatsApp application we studied. why?
1. End-to-end encryption: when the messages are encrypted, they can only be deciphered on the device of the recipient of the message. This means that even if the adversary can intercept the encrypted messages, he cannot read the content without the encryption keys. This encryption makes it difficult for the attacker to directly access the content of the messages, and understand which messages are related to which group.
2. Mixing messages: Messages from different groups or conversations are often mixed in the network traffic. This mixing challenges the attacker to distinguish between messages belonging to different groups. They can observe the traffic flow and the size of the messages, but without access to the encryption keys, it is not possible to determine the exact content or which messages belong to which group.
3. Packet size and timing: While the content of messages is encrypted, certain metadata such as message timing, size and frequency of communication are still visible to an attacker. However, as we have seen in the work, metadata alone may not be sufficient to reliably correlate an individual's presence in multiple groups. For example, multiple groups may have similar movement patterns, which becomes a challenge.
4. Multiple identities: frequent users, use several platforms when they enter the application, such as from the computer/phone.
This means that even if the attacker watches multiple interactions from different devices, he cannot definitively link them to the same person.
Furthermore, users may switch between devices or change their identity, further complicating the process.

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Website: urtech.ca
Publication Date: July 2020
URL: https://www.urtech.ca/2020/07/how-to-verify-that-whatsapp-messages-are-encrypted/

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Title: "Practical Traffic Analysis Attacks on Secure Messaging Applications"
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AI Chatbot:
Assistant: ChatGPT
Description: AI language model developed by OpenAI, based on GPT-3 architecture, providing text-based assistance and information.
Knowledge Cutoff: September 2021