Analysis of Group-Based Communication in WhatsApp

Michael Seufert[1(✉)], Anika Schwind[1], Tobias Hoßfeld[2], and Phuoc Tran-Gia[1]

[1] Insitute of Computer Science, University of Würzburg, Würzburg, Germany
seufert@informatik.uni-wuerzburg.de
[2] Chair of Modeling of Adaptive Systems, University of Duisburg-Essen, Essen, Germany
tobias.hossfeld@uni-due.de

Abstract. This work investigates group-based communication in WhatsApp based on a survey and the analysis of messaging logs. The characteristics of WhatsApp group chats in terms of usage and topics are outlined. We present a classification based on the topic of the group and classify anonymized messaging logs based on message statistics. Finally, we model WhatsApp group communication with a semi-Markov process, which can be used to generate network traffic similar to real messaging logs.

Keywords: Group-based communication · WhatsApp · Survey · Classification · Semi-Markov process · Network traffic model · Mobile instant messaging · Group chats · Mobile networks

1 Introduction

Today, our everyday life cannot be imagined without the possibility of mobile communication. On smartphones, especially text-based communication like Short Message Service (SMS) and Mobile Instant Messaging (MIM) is used by a large share of the population. Currently, WhatsApp is the most popular MIM application in the world having around 700 million monthly active users [5], followed by QQ Mobile and Facebook Messenger, which are both used by more than 500 million users [7]. The advantage over the traditional SMS is that MIM services are mostly free and not only text messages but also media like videos, images, and audio messages can be transmitted easily.

In contrast to SMS, MIM applications use the Internet to exchange messages. Thus, ubiquitous communication through MIM applications increases the Internet traffic and puts a lot of load on mobile networks. Therefore, MIM applications and their usage have to be investigated to efficiently handle the increasing traffic and provide a proper management of the cellular resources.

One of the most popular features of MIM applications is group chatting. WhatsApp, for example, allows users to communicate in a group with up to 100 members. In contrast to regular chatting, a post in a group has to be transmitted

R. Agüero et al. (Eds.): MONAMI 2015, LNICST 158, pp. 225–238, 2015.
DOI: 10.1007/978-3-319-26925-2_17

to multiple recipients, and thus, multiplies the traffic on the network. In order to develop new mechanisms, which cope efficiently with the increasing traffic but also guarantee a high user satisfaction, it is necessary to understand group-based communication in detail.

The goal of this paper is to analyze group-based communication in WhatsApp, to classify WhatsApp groups, and to model the communication in groups and the resulting network traffic. Therefore, this work is structured as follows:

First, relevant related work will be presented in Sect. 2. Section 3 will describe the user study and present results about the participants' WhatsApp usage and the ratings of their groups. In Sect. 4, anonymized group chats logs are analyzed, and first approaches to classifying WhatsApp groups are outlined in Sect. 5. Finally, Sect. 6 presents a semi-Markov process for generating realistic WhatsApp conversations in groups, and Sect. 7 concludes.

2 Related Work

In this section, recent research papers are summarized, which relate to our work. They include a comparison of SMS and MIM, studies about mobile group-based communication, and works investigating WhatsApp and its impact. Nevertheless, our study is the first work to analyze group-based communication in WhatsApp based on a survey and the analysis of messaging logs.

Comparison of SMS and MIM. To understand the reasons for the success of WhatsApp, it is important to relate it to other types of communication. Church and de Oliveira [1] compare MIM behaviors with traditional SMS communication. Their research focuses on the motives and perceptions of the usage of WhatsApp and what this service offers above and beyond traditional SMS. By conducting interviews and a survey, they worked out that neither technology is a substitute for the other. SMS costs significantly impacts people's frequency of usage and is, together with social influence, one of the main reasons for today's migration to MIM applications like WhatsApp. According to the authors, WhatsApp messages tend to be more social, informal, and conversational in nature, whereas SMS is seen as more privacy preserving, more formal, and generally more reliable.

Group-Based Mobile Messaging. Considering research about group-based communication, Counts and Scott [2] demonstrate interesting results. In their paper, the authors develop a group-based mobile messaging application called "SLAM", which offers features comparable to group chats in WhatsApp. Afterwards, they analyze the communication in relation to its social impact. It should be kept in mind that this paper was published in 2007, two years before WhatsApp was released. The paper shows in which ways and to what dimension group-based messaging improves the social and leisure aspects of communication. They found out that participants used group-based messaging for roughly the same purposes as one-to-one messaging. However, by analyzing the message volume, it becomes clear that participants sent significantly more messages in groups than in one-to-one conversations. In a survey conducted by the authors, participants state that mobile communication is more fun in a group than in one-to-one communication.

Research about user satisfaction with mobile messaging applications was published by Park et al. [6] in 2014. By conducting a survey with 220 users of MIM apps, the authors analyze factors affecting user satisfaction. They found out that self-disclosure, flow, and social presence significantly affect user satisfaction. Nevertheless, the feeling of being together everywhere and at any time is specified as the most important factor of satisfaction by the respondents.

WhatsApp. Network-related aspects of communication were covered by Fiadino et al. [4] in 2014. In their paper, they analyze the traffic behavior of WhatsApp. According to the authors, WhatsApp is a fully centralized service. It is hosted by the cloud provider SoftLayer in the United States. They work out that WhatsApp is mainly used as a text-messaging service, with more than 93 % of the transmitted flows containing text. However, 36 % of the exchanged volume in uplink and downlink are caused by video sharing, and 38 % by photo sharing and audio messaging.

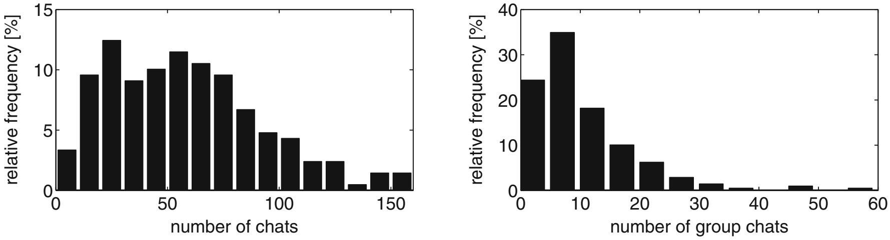
There is also research about the impact of WhatsApp on its users. In 2014, Yeboah and Ewur [8] investigated the influence of the use of WhatsApp on the performance of students in Ghana. According to their paper, the application makes communication easier and faster, but 76 % of the interviewed students think the use of WhatsApp has rather negative than positive effect on their studies.

3 User Study on WhatsApp Usage

In order to obtain reliable data, we conducted a study on the usage of WhatsApp. Therefore, more than 200 people were consulted during three days in the end of November 2014 on the campus of the University of Würzburg, Germany. The participants answered the questions of the survey in a separate room using personal or laptop computers. On average, this took 15 min. The survey was divided by topics into three different parts. Each part contained various questions that were presented on individual pages. Questions had to be answered using text fields, single choice, or multiple choice options.

After collecting demographic data about the participants, they had to specify details about their usage of WhatsApp in the first part. The next part dealt with the network usage statistics that WhatsApp collects automatically on every device. Finally, the focus of the questions was moved to the individual WhatsApp group chats the participants had on their devices.

After taking part in the survey, the participants were also asked to send some of their messaging histories from WhatsApp group chats. The results of the analysis of these messaging histories will be discussed in Sect. 4.



(a) Dist. of the number of chats (b) Dist. of the number of group chats

Fig. 1. Distribution of the number of chats and the number of group chats of each participant of the survey

In total, 243 participants took part in the study. Because of invalid answers to some questions, the records of 34 people were removed for the following analysis. Invalid answers were, for example, implausibly high values in the network usage (i.e., more than ten times the average network usage) and a negative value or zero in questions, in which only positive numbers could make sense. After filtering out participants with invalid answers, 209 participants remained – 106 (50,72 %) female and 103 (49,28 %) male. The youngest participant was 17 and the oldest 29 years old; the average age was 21.4 and the median age was 21. The relatively low average age can be explained by the fact that most of the participants were students. The following paragraphs show the most important results of the statistical evaluation of the answers.

Usage of WhatsApp. In the first part of the survey, the participants had to count how many chats in total they had on their devices and how many of these chats were group chats, i.e., chats with more than one partner. Figure 1a shows a bar plot of the binned distribution of total number of chats per user. The width of each bar is ten. It can be seen that only 3.35 % of the participants had ten or less chats and 12.44 % of the participants had more than 100 chats. The maximum number of chats was 158, the minimum was 3. The average number of chats, i.e., the average number of people with whom messages were exchanged, was 59 (median 56). It follows that WhatsApp is an important means of communication for many people as they use it to send messages to a large number of different people.

Figure 1b shows the binned distribution of the number of group chats per user. Here, the width of each bar is five. The mean number of group chats was 10 (median 8) and the maximum was 59. Only 1.91 % of the participants had no group chats at all. Please note that it is possible to delete group chats and the participants indicated during the study that they had already deleted on average 7 groups (median 3).

Looking at the share of group chats among all chats, only 6.7 % of the participants had less than 5 % group chats in all chats. Most participants (83.28 %) had a ratio of group chats in all chats between 5 % and 30 %. All in all, it

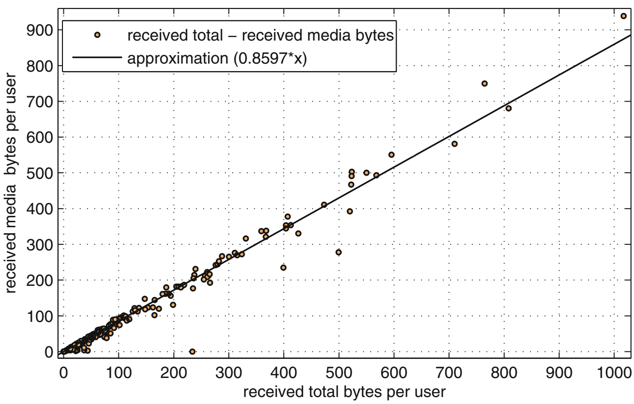


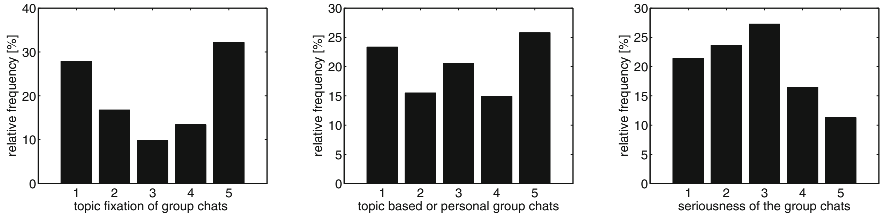
Fig. 2. Relation between received media bytes and received bytes in total per person

can be assumed that the group chat feature is used frequently by nearly every WhatsApp user, which makes it a key function of WhatsApp.

The next set of questions was about the frequency of the participants' usage of WhatsApp and SMS. The evaluation of the answers showed that WhatsApp is used significantly more often than SMS. 85.17 % of the participants indicated that they use WhatsApp at least every two or three hours, whereas only 6.69 % use SMS so frequently. Most participants (80 %) use SMS at most one or two times a day. This leads to the conclusion that WhatsApp communication was preferred considerably to SMS communication by the participants.

Network Usage. In this part, the participants were asked to copy the numbers of WhatsApp's network usage from their device. On an Android device, for example, these statistics can be accessed from the menu at Settings – Account – Network Usage. On average, the participants sent 11936 and received 17753 messages, which includes both media and text messages. The average amount of the sent media data is 86.88 MB and that of received media data is 141.69 MB. Also, on average every person sent 33.46 MB and received 69.82 MB in text messages. In total, 78.27 MB were sent and 348.99 MB were received by an average participant. It must be taken into account that the time of WhatsApp usage is different for each participant and that statistics of WhatsApp's network usage can be manually reset and also start from zero when changing the device.

Considering the relation between received media bytes and received bytes in total, a high Pearson correlation coefficient of 0.92 can be determined. Figure 2 shows this correlation by representing each participant by the number of total bytes (x-axis) and the number of media bytes (y-axis) he or she received. The relation between received media bytes and received bytes in total can also be approximated by a linear function. In this case, $f(x) = 0.8597 \cdot x$ provides a very good approximation indicated by the very high coefficient of determination $R^2 = 0.9739$. Thus, nearly 86 % of the bytes sent can be attributed to media



(a) Topic fixation of a group, from one single topic (1) to multiple topics (5)

(b) Distribution of the answers if the group is topic based or personal

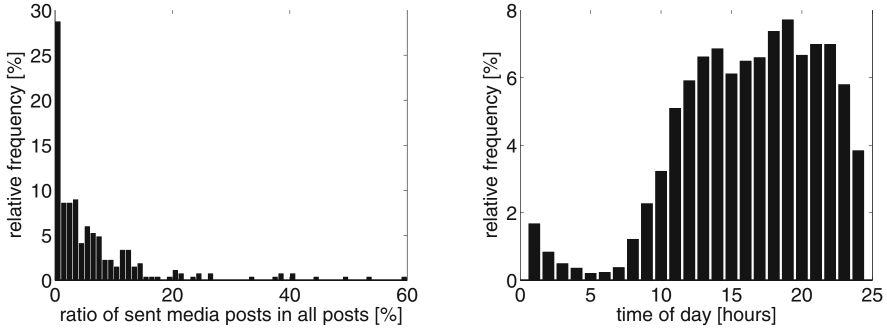
(c) Distribution of the answers whether the group has serious content or not

Fig. 3. Analysis of the content of the groups with ve-point Likert scale ranging

posts, i.e., photos, videos, or audio messages. This indicates that media posts cause the largest part of WhatsApp's network traffic.

WhatsApp Groups. In the last section, the participants had to answer several questions about every WhatsApp group chat, up to 20 group chats, they had on their phone. First, the participants were asked about the number of members in each group chat and how many of these they did not know. Note that the creator of the group chat has to invite each partner to the group chat individually from the contact list of his device. Although WhatsApp allows to create group chats with up to 100 members, the majority of group chats analyzed in the survey contained only few members (mean 9, median 6). In terms of unknown members, the group chats had an average of 1 per group and the median was 0. This leads to the assumption that WhatsApp group chats are mainly used for communication with specifically selected members who knew each other.

In the following, the topic of the group chats was investigated. At first, the participants had to indicate whether the subject of each group chat was a unique event, a repetitive event, or no event. 21.96 % of the group chats dealt with a unique event, 21.47 % with a repetitive event, and 56.57 % with no event at all. Next, the participants were asked to rate the topics discussed in the group chats on a five-point Likert scale from single topic (1) to multiple topics (5). Figure 3a shows that most of the group chats had one single topic (27.75 %) or multiple different topics (32.16 %), but rarely something in between. Figure 3b shows the distribution of the answers whether the group chat is focused on the topic (e.g., a birthday present) or on the persons (e.g., a soccer team). Here, the five-point Likert scale ranges from topic based group (1) to personal group (5). It can be seen that the distribution of the answers is nearly constant. Only the extremes, topic based (23.04 %) and personal (25.78 %), are slightly increased. Figure 3c shows the distribution of the seriousness of the group chats. The bars of the chart represent a Likert scale from trivial and amusing content (1) up to serious content (5). It becomes obvious that while very few groups had serious or mostly serious content (27.55 %), most groups had either both serious and trivial content (27.25 %), mostly trivial (23.63 %) or very trivial content (21.37 %).



(a) Dist. of ratio of media in all posts (b) Distribution of posts over the daytime

Fig. 4. Distribution of the ratio of media posts in all posts of a group chat and of the interarrival time of all posts

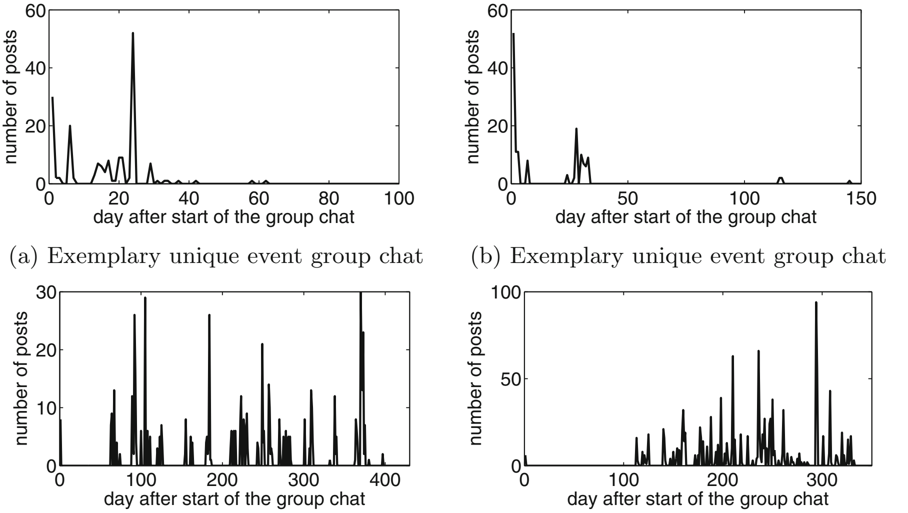
4 Analysis of Group Chat Logs

After taking part in the survey, the participants were asked to send some of their messaging histories from WhatsApp groups. In order to protect the users' privacy, these histories were anonymized. For each message, we only kept a time-stamp as well as a unique user ID, the number of sent characters and a hash value of the message. Some participants gave their consent to also keep their original data for further investigations. In that way, 271 anonymized and 131 original messaging histories have been collected.

General Information About the Messaging Histories. First, we present a short statistic about the collected data. In total, the 271 group chats had 224 658 posts. The maximum number of posts in a group chat was 16 202, the minimum 3. On average, a group chat had 832 posts and the median was 186.

72.76 % of all posts consist of less than 40 characters. Furthermore, 8.26 % of the text post consist of only one ore two characters or emoticons. Only 1.84 % of the text posts consist of more than 160 characters. It shows that long messages, which are an advantage of MIM considering the limited length of SMS messages, are rarely sent. This leads to the conclusion that the participants mainly used WhatsApp similar to SMS and rarely sent completely formulated sentences.

Ratio of Media Posts in All Posts. Fig. 4a shows the distribution of the ratio of media posts in all posts of a group chat. 59.32 % of all group chats have less then 5 % media posts in all posts, 28.70 % have less than 1 % media posts in at all posts. The distribution of the ratio decreases very fast between 0 % and 20 % and then approaches zero. This leads to the conclusion that group chats in WhatsApp are mainly used to communicate via text posts, while media posts were only used to some extent. However, as Sect. 3 shows, media posts cause the largest part of WhatsApps network traffic.



(a) Exemplary unique event group chat (b) Exemplary unique event group chat

(c) Exemplary repetitive event group chat (d) Exemplary group chats with no event

Fig. 5. Examples of the distributions of the number of posts per day

Temporal Evaluation of the Chat Histories. First, the frequency of posts at a particular time of day was investigated. Figure 4b illustrates the daytimes in hours (x-axis) in connection with the relative frequency of posts (y-axis). Mosts posts were sent between 7 pm (7.72 %) and 6 pm (7.38 %), fewest between 5 am (0.20 %) and 6 am (0.24 %). The chart shows the trend that only 18.35 % of the posts were sent in the morning or noon between 6 am and 1 pm.

Next, the interarrival times of messages in group chats were analyzed. 59.32 % of the posts were immediate responses and had an interarrival time of less than one minute. 80.90 % of all messages have an interarrival time of less than 15 min. Moreover, only 15.10 % of all interarrival times are 30 min or longer. These findings supports the statement that WhatsApp constitutes a very fast communication.

5 Classification of WhatsApp Groups

In this section, we investigate different characteristics of groups, i.e., whether different categories exist in which WhatsApp groups can be classified. Therefore, we follow a naive approach and use the *Density-based spatial clustering of applications with noise (DBSCAN)* algorithm [3] to compute clusters based on the group characteristics, which were reported by the participants of our study (cf. Sect. 3). Three clusters could be observed in the answers of the participants. The main distinctive feature of these clusters was whether the topic of the group chat was a unique event, a repetitive event, or no event. In the following, the properties of the clusters (mean ratings on the respective Likert scale) are presented:

Unique Event. Group chats belonging to this class deal with a unique event. Therefore, on average these group chats had mainly one single topic (1.53) and were rather topic based than personal (2.09). On average, the content was neither very serious nor trivial (2.23). In total, 222 (21.81 %) group chats described in the survey fit into this class.

Repetitive Event. All group chats in this class deal with a repetitive event. On average, the group chats in this class had rather a single than multiple topics (2.18). They also were rather topic based and their content was neither very serious nor trivial (2.17). 216 group chats described by the participants (21.22 %) belonged to this class.

No Event. This class contained group chats which deal with no specific event. They had on average rather multiple topics (3.96) and are also rather personal (3.67). The seriousness of the group chats were rather low (1,35). Of all group chats described in the survey, 577 (56.68 %) were allocated to this class.

To classify groups in an automated manner, further properties had to be determined from messaging histories. Therefore, some of the original, non-anonymized messaging histories were selected according to their group name and analyzed. This means, if the group name clearly indicated that the subject of the group was a unique event (e.g., a birthday party), a repetitive event (e.g., a regular social gathering) or no event (e.g., a group of family members), this group was used to find further properties.

Figure 5a and b show two exemplary distributions of the number of posts per day of unique event groups. Here, every day after the creation of the group chats was labeled on the x-axis and the number of posts per day on the y-axis. It is noticeable that both have a very short duration (shorter than 150 days). It can also be seen that both plots have one distinct maximum and otherwise a mostly low number of posts per day. The left figure has its maximum at 52 posts per day. The second highest number of posts per day is 30, which is only 58 % of the maximum. Similarly to this, the right figure has one clear maximum (52 posts per day) and has a great distance to the second highest number of posts, which only has 40 % of the maximum. This characteristic distribution of the posts was visible at all original messaging histories classified as unique events.

In Fig. 5c, there is an exemplary plot of the distributions of the number of posts per day of a repetitive event, while Fig. 5d shows an exemplary plot of a no event group chat. Here, no distinct maximum can be found. The left figure shows two maxima with 29 and 30 posts. The right figure has a maximum of 94 posts. The second highest number of posts per day is 66, which is 70 % of the maximum. By comparing them using this distribution, no significant difference of behavior can be determined. Both classes have a longer duration than group chats dealing with unique events (about 400 days) and also several spikes. Surprisingly, no obvious regularity can be found in the plot of the repetitive event. Contrary to the expectations raised by the answers to the survey, the original messaging histories showed no differentiation between group chats dealing with repetitive events and no events.

In the following, a classifier for the detection of a unique event group from anonymized messaging histories will be presented. Based on the properties observed above, we classify a group chat history as a unique event when the following conditions hold: A group chat, which deals with a unique event, has a maximum duration of half a year. It also contains one day on which the most posts were sent and the second highest number of posts is not more than 60 % of the maximum. By checking all collected anonymized messaging histories, 87 (32 %) group chats were classified as unique event groups. Compared to the classification on the basis of the survey, about 10 % more unique events were detected than expected. As the participants only sent a limited number of messaging histories of all of their group chats, they certainly had selected consciously which history they wanted to send. Thus, the participants might have chosen less personal and less private group chats with a higher frequency, which could be the reason of the higher rate of unique events in the messaging histories. Nevertheless, the presented approach can be seen as a first step towards classification of group chats, although its performance has to be validated based on more original messages in future work.

6 Model of Group Communication

The previous sections evaluated the answers of the survey and the collected messaging histories. In this section, these results are used to create a communication model of a group chat history, based on a semi-Markov process. This model could, for example, be used to estimate the network traffic of WhatsApp group chats.

In this model, only media posts and text posts are considered. Figure 6 illustrates the activity model of the WhatsApp group communication. The probability that a media post is followed by another media post is 30.55 %, which means that the probability that a text posts follows is 69.45 %. With 94.71 %, a text post is followed by another text posts; thus, it is followed by a media post with a probability of 5.29 %. These probabilities have been obtained from the analysis of the messaging histories by counting the frequency of occurrence of each transition.

This activity model can be transformed into a semi-Markov process by converting each transition into a model state and additionally taking the corresponding interarrival times (IAT) of the messages to account how long the

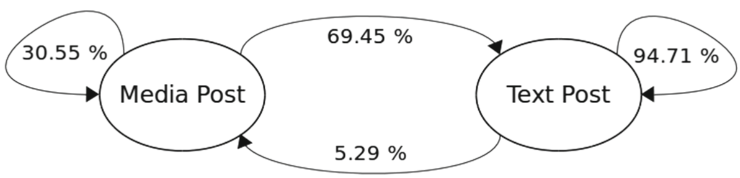
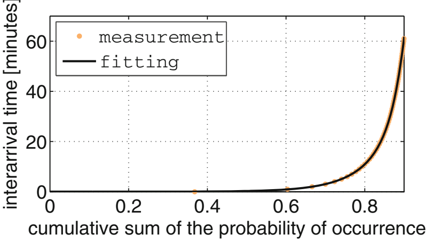


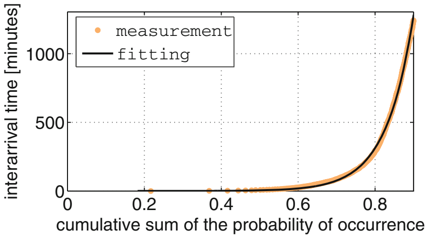
Fig. 6. Activity model of WhatsApp group communication

Table 1. Percentiles of the interarrival times of the different transitions in minutes

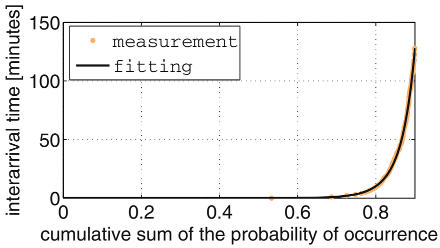
Transition	90 %	99 %
text post - text post	63	1066000
text post - media post	1244	613600
media post - media post	129	35670
media post - text post	81	302300



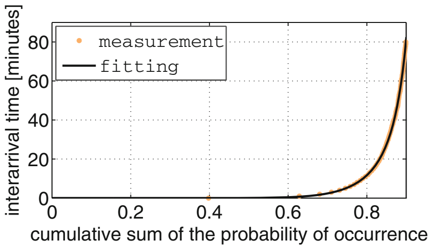
(a) Transition "text post - text post"



(b) Transition "text post - media post"



(c) Transition "media post - media post"



(d) Transition "media post - text post"

Fig. 7. Inverse cumulative distribution function of the interarrival times of the different transitions

semi-Markov process will stay in the respective state. We excluded IAT values above the 99 % percentile, which are unrealistic and were caused, for instance, by message log modifications when changing to a new smartphone. Moreover, we split the measured interarrival times at the 90 % percentile. The observed IATs below this percentile can be accurately fitted, however the IATs above do not show regular behavior, which is due to phases of inactivity during the group conversation. To approximate these phases, we use a uniform distribution for the 10 % of IATs which can take values from the 90 % percentile to the 99 % percentile. The respective percentiles are listed in Table 1. Note that phases of inactivity in the groups, which are usually modeled as on/off-processes, are not considered explicitly in this work. However, the presented approach can be easily extended, e.g., by adding a state for inactivity.

We implemented a Java discrete event simulation to generate realistic network traffic for group conversations. To create random numbers, which follow the interarrival time distribution, inverse transform sampling was applied.

Table 2. Approximation of the interarrival times of the different transitions

Transition	α_1	β_1	α_2	β_2	β_3	γ	R^2
T – T	$6.756 \cdot 10^{-4}$	11.99	$1.763 \cdot 10^{-12}$	33.79	41 670	37 441	1
T – M	$3.899 \cdot 10^{-3}$	14.11	0	0	110 550	98 251	0.9984
M – M	$1.207 \cdot 10^{-15}$	42.41	$3.196 \cdot 10^{-7}$	21.51	41 890	37 572	0.9984
M – T	$3.224 \cdot 10^{-5}$	15.99	$4.672 \cdot 10^{-20}$	52.99	29 250	26 244	0.9996

Figure 7 shows the inverse cumulative distribution functions of the interarrival times of all possible transitions "text post - text posts", "text posts - media post", "media post - media posts", and "media posts - text post", below the 90 % percentile. The x-axis shows the cumulative sum of the probability of occurrence while the interarrival time in minutes can be seen on the y-axis. As described above, the values above the 90 % percentile are approximated by a uniform distribution, which gives a linear inverse cumulative distribution function. Thus, the inverse cumulative distribution function of the interarrival times of the different transitions can be approximated using the following scheme:

$$f(x) = \begin{cases} \alpha_1 \cdot exp(\beta_1 \cdot x) + \alpha_2 \cdot exp(\beta_2 \cdot x) & x \leq 0.9 \\ \beta_3 \cdot x - \gamma & else \end{cases}.$$

Table 2 shows the parameters of the four transitions, where T is a text post and M is a media post, and the coefficient of determination R^2, which indicates the goodness of the fitting of the exponential part.

With the Java implementation of the described semi-Markov process, 150 group chats with a duration of 3 months were created. As a counterpart, also 150 extracts of the original messaging histories, with a period of 3 month, were randomly selected. The only condition for these extracts was that they had to be active parts of a group chats, which we defined as a minimum of 30 posts in 3 months. According to the results of [4], media posts have on average a size of 225 KB and text posts a size of 6.7 KB. Thus, every post was weighted on the basis of these results. Note that this is the traffic as observed by an individual user without any distinction between uplink and downlink traffic. For better comparison, the average cumulative sum of the bytes per day was calculated, which is shown in Fig. 8. The x-axis labels the number of day from day 0 up to 91 (three months), while the y-axis shows the cumulative sum of sent KB. The black graph shows the average cumulative sum of KB per day of the original messaging histories, the brown graph shows the average cumulative sum of the simulation model. On average, an original messaging histories generated 11 545 KB and the simulation model 11 711 KB network traffic per group member within three month. The difference is therefore only 166 KB. The maximum difference of the cumulative sum of the bytes per day is 1 044 KB on day 30. Therefore, the presented communication model constitutes a good way to simulate network traffic generated in WhatsApp group chats.

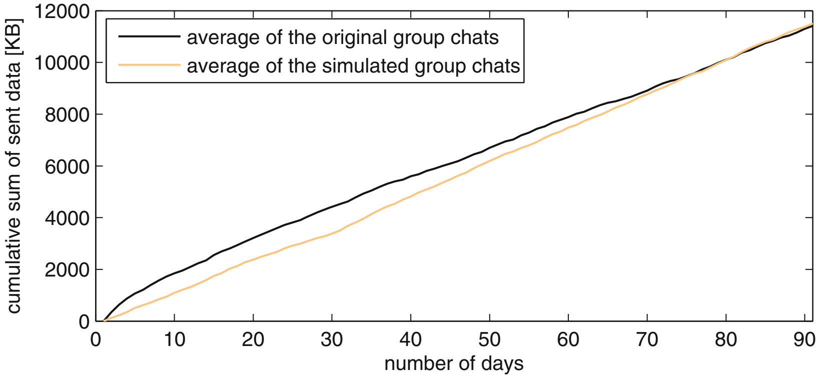


Fig. 8. Cumulative sum of sent KB per day of the original messaging histories and the simulation model

7 Conclusion

This paper investigated group-based communication in a popular MIM application. By conducting a survey and evaluating messaging histories, statistics of group chatting in WhatsApp were obtained. Moreover, a classification of group chats was presented and a model for group communication was developed. These insights and results lay the foundations for future research on group-based communication and can help to efficiently handle traffic generated by MIM applications.

It could be confirmed that WhatsApp users utilize this application significantly more often than SMS. The survey also indicated that, for many people, WhatsApp has become an important means of communication in many conditions of life. It became clear that the main distinctive feature for the classification is whether the topic of a group chat was a unique event, a repetitive event, or no event. By applying these classes to the messaging histories, further properties of the classes could be determined.

A classification method was created, which is able to decide whether a messaging history deals with a unique event or not. According to this method, approximately one third of the collected messaging histories deal with a unique event, and thus, have a limited lifespan. These results came close to the findings from the survey.

Finally, a communication model of a WhatsApp group chat based on a semi-Markov process was developed. Its transition probabilities are based on the probability of occurrence of certain message sequences and each transition takes the respective interarrival time distribution of the subsequent message into account. This model was used to simulate network traffic of WhatsApp group chats. The evaluation of the simulated traffic showed similar properties to network traffic caused by original messaging histories. Thus, this simple model can already be used for the performance evaluation of the WhatsApp service in mobile networks.

In future work, more messaging histories of WhatsApp will be collected and evaluated. Moreover, a refined model, which takes phases of inactivity more explicitly into account and also considers the distribution of message sizes, will be developed. This will allow for a more accurate performance evaluation of existing or the development of novel traffic management mechanisms in mobile networks.

Acknowledgement. This work was partly funded by Deutsche Forschungsgemeinschaft (DFG) under grants HO 4770/1-2 and TR257/31-2, and in the framework of the EU ICT Project SmartenIT (FP7-2012-ICT-317846). The authors alone are responsible for the content.

References

1. Church, K., de Oliveira, R.: What's up with Whatsapp? Comparing mobile instant messaging behaviors with traditional SMS. In: Proceedings of the 15th International Conference on Human-computer Interaction with Mobile Devices and Services, pp. 352–361 (2013)
2. Counts, S.: Group-based mobile messaging in support of the social side of leisure. Comput. Supported Coop. Work **16**, 75–97 (2007)
3. Ester, M., Kriegel, H.P., Sander, J., Xu, X.: A density-based algorithm for discovering clusters in large spatial databases with noise. In: Kdd, pp. 226–231 (1996)
4. Fiadino, P., Schiavone, M., Casas, P.: Vivisecting Whatsapp Through large-scale measurements in mobile networks. In: Proceedings of the 2014 ACM Conference on SIGCOMM, pp. 133–134 (2014)
5. Koum, J.: Facebook post (2015). https://www.facebook.com/jan.koum/posts/10152994719980011?pnref=story. Accessed on 26 January 2015
6. Park, S., Cho, K., Lee, B.G.: What makes smartphone users satisfied with the mobile instant messenger? Social presence, flow, and self-disclosure. Int. J. Multimedia Ubiquit. Eng. **9**, 315 (2014). Please check and confirm the edits made in Ref. [6]
7. Statistica: Most popular global mobile messenger apps as of December 2014, based on number of monthly active users (in millions) (2014). http://www.statista.com/statistics/258749/most-popular-global-mobile-messenger-apps/. Accessed on January 26, 2015
8. Yeboah, J., Ewur, G.D.: The impact of Whatsapp messenger usage on students performance in tertiary institutions in Ghana. J. Educ. Pract. **5**, 157–164 (2014)