

Measure of User Behaviour before and during Disaster Congestion

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Abstract— Network congestion during large scale disasters seems inevitable. Sudden influx of traffic caused by users calling their loved ones, coupled with the possibility that many base stations and routers in the area are damaged by the disaster; leads to resource shortage which causes congestion, which in turn causes many users becoming disgruntled and their quality of experience dropping. If a study can be made on predicting user behaviour, based on usual user habits and way of acting immediately after a disaster, then the network provider can regulate traffic accordingly or take precautions in areas within disaster zones.

Keywords— Quality of experience, User behaviour, Congestion control, Social network, Quality of service

I. INTRODUCTION

Congestion caused by large scale disasters is a great problem network providers must deal with eventually. Not only network resources get damaged during the disaster, but also most users aware of the scale of the recent disaster create an increase in online traffic, which increases proportional to the scale of the disaster, often exponentially. Most service providers usually deal with this with over sourcing, that is, installing more units than needed or actually building more station within a certain cell. In case of increasing traffic within a certain area, which is more often than not caused by a gathering of many people, like protests or concerts, the easiest solution seems to be dispatching mobile station teams, which serve as temporary base stations. These solutions however, are expensive; laborious or simply not enough to deal with this problem.

Recent studies show that mobile users of today are mostly dominated by smart phone users of always-online variety, with a majority in their early twenties-late thirties. These users are also within the phone companies' target demographic since most mobile online services (especially social media, search engines and social games) are targeted within this range. It is open for debate that this demographic is the one with the highest access to web services [1], and will be biggest contributor to congestion during a disaster.

Normal time user behaviour is affected mostly by user

habits and networks capability of satiating said habits. User habits can be explained as the sum of a user's online time, daily usage of the network and the daily hours of their calls. As shown in Figure 1, user's past behaviour and daily habits contribute to actually map predicted behaviour. User behaviour immediately after a disaster can be summed up as, quick short calls of varying length and/ or immediate web service access of usually short intervals. This is due to the fact that most users are concerned about the well-being of their relatives and friends and either they call them directly or access the internet to gather information about the scale of damage and post and follow their contemporaries on social media. In our case, it is agreed upon that this demographics' behaviour will be more predictable and considering their effect on the overall user traffic, more beneficial for study. If their behaviour can be mapped, the service provider can regulate traffic accordingly and either downsize or limit each user type's access, letting them have just the right amount of traffic they need and using the resources sparingly [2].

This paper is as follows: In section II we introduce some works done on the subject, In section III, we deal with the test we made to discover usual user behaviour of target demographic immediately after a disaster scenario. In section IV, we examine the results of an online research made for this purpose. Section V includes ideas and strategies that can be used to fight congestion, gathered from the data introduced in the test and survey. Section VI concludes the paper.

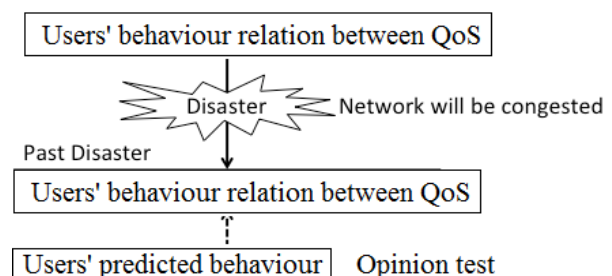


Figure 1. Main aspects of user behaviour specifications and research goal

II. RELATED WORKS

Similar works to understand user behaviour has been done before, in order to create a user demographic which would make it easier for both provider and statisticians to accurately map the predicted outcome of a given situation. Yamakami's research was based on an aging analysis, using threshold values to predict mobile user presence in a given month [1]. While Liqin et al.'s work used Bayesian network and created user attributes, taking advantage of the three aspects of a given scenario: evidence accuracy, accuracy of comparison between evidences and times of interaction to influence prior-probability, creating user priority for a more secure network [2]. Zhao et al. created a user behaviour architecture, again relying on related information and past behaviour and needs of users and collectively mine this data to provide personal benefits, to further economic gain for both user and provider [3]. Liqin et al. proposed a similar behaviour prediction method for future networks [4].

There are additional works on disaster scenarios, mainly [5], [6] and [7] but these works focus more on managing network resources pre and post-earthquake and study of user behaviour before and after large scale disaster scenarios to better distribute resources is still a discussed issue, and a hands-on approach must be provided.

III. VOICE BASED APPLICATION TEST TO DETERMINE USER BEHAVIOUR

To gather data on user behaviour, a subjectivity evaluation test; with ten people as test subjects, ages between 23 and 33, has been made. Subjects were uninformed of the nature of the test beforehand, and were asked the following questions.

1. How much time do you spend online? Are you a member of a social network?
2. How many calls do you make in one day? How long do they last?
3. Have you experienced congestion before? Which annoys you more, dropped calls or sound quality?

For the data, each subject is told that in case a disaster of as-of-yet unknown scale has struck and asked what their communication schedule would be. Following this, they were asked questions on different subjects as to whom they can call, how long each of their calls would last, how many calls they would make and so on. After their initial explanation based on whom they call, how much each call would last and the web based action plan, they were given access to a voice based web application to simulate their call. In the test we used a smart phone and a laptop PC, and the application Skype installed in both. In our case Skype is called due to its popularity and ease of use. The catch, however, is that the net speed is strictly controlled by the tester, whom the call is directed to. For this purpose, the Net-Peeker program is used to monitor and downsize the speed of the application. Speed varied between 10 Mbps and as low as 50 Kbps, in which case the call usually dropped. As shown in Figure 2; subjects first answered personal questions regarding to their daily habits and possible behaviour based on experience. After their answers were noted, they made their calls to the test taker (as

if they were calling someone they would call in this given situation), who controlled the nature of the calls and changing the speed according to Table 1, thus making sure the subject experiences differing speeds on at least 4 calls, the hindrance it imposes on the calls and heavy-traffic caused congestion. All the while the second tester gives his findings to the first, noting user's waiting time between calls, their holding time to relay information and finally their given opinion score and level of satisfaction through each call that is made.

It also had the effect of varying connection times, lower sound quality and distortion and varying holding times on the call. Subjects made their calls with their survey answers in mind, each with different speed, duration and quality. They were then asked to rate the service they were given on the opinion scale value.

This value contributed to an average opinion score. To make the test more systematic, we used the MOS (Mean opinion score) values for VoIP as a guide for the test subjects, in this case; they were told to give a score of their completed calls based on MOS scale of Table 2. The average MOS of the limited bandwidth calls is then calculated.

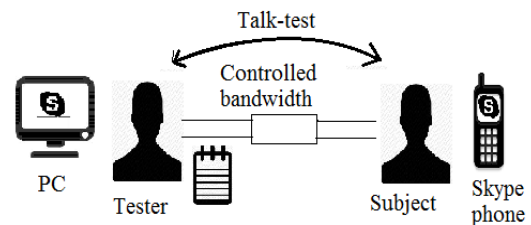


Figure 2. Flow of MOS test with one participant and two testers

TABLE 1. MOS FOR GIVEN NET SPEED

Transmission speed	MOS
Max speed, up to 10 Mbps	4.4
Speed randomly changing between 10 Mbps-50 kbps	2.5
Speed between 50 kbps and 2 Mbps	1.6
Speed changing from 8 Mbps to 50 kbps	2.8

TABLE 2. MOS SCALE

MOS scale	Description
5	Perfect. Like face-to-face conversation or radio reception.
4	Fair. Imperfections can be perceived, but sound still clear.
3	Annoying.
2	Very annoying. Nearly impossible to communicate.
1	Impossible to communicate.

Out of 10 test subjects; 9 people had access to social media, which they checked regularly. 7 expressed the need for web services instead of voice call during congestion. 9 were more annoyed by dropped calls to the point of considering them

unacceptable. 8 noted that the first person they would call would be a family member or a close friend, while only 1 would call government officials for information.

Of the 9 with social network memberships, 6 said that they would post information regarding their well-being and all of them said they would check their social network first (mainly Facebook and Twitter) instead of a news agency's website. For only 2 users, sound quality actually mattered. During the test, subjects made their calls through Skype, and were told to make as many calls as they would during congestion, hindered by differing and obstructing net speed simulating their subsequent calls and slow-down caused waiting times, while none of them used video call option on a regular basis or none at all. For maximum bandwidth the average MOS was 4.4 and the overall MOS evaluation (for limited speed calls) was 2.3 with users rating very low (1 or 2) when their call was cut short within the first minute mark. Subjects were inclined to be brief in their calls after they realized their call may drop and also they kept making subsequent calls in shorter intervals every time their call did not connect.

From this result we gathered that web service accessibility during first hours of disaster is a must because a great number of users within our demographic would need them for first-hand information and personal announcements. In the voice call, major concerns would be to have continuous call times of at least a minute, while call quality and waiting times are less of a concern. Since most users would call their family members, tariffs including those members for easy access should be considered as a priority.

IV. WEB BASED SURVEY AND RESULTS

To determine if our test can be integrated on a more general public basis, we introduced an online survey to be filled by users, according to their past experiences, their usual habits and their daily usage. 71 users took the test, whose occupations include architects, engineers, doctors and managers while most are listed as students of varying degrees. The test consisted of 26 questions, regarding the person's daily web usage, their mobile behaviour, their opinion about a given service and their self-predicted behaviour during disaster times and congestion. Users' opinions about solutions and even some demands are taken into consideration. Their occupation is considered a factor in some of their given behaviour (i.e. 30 calls/day for a company manager would be considered normal, although unlikely for a student) so some extreme answers were omitted. Age and nationality of the users are asked to create a multi-national demographic of users and to give a broader perspective over the habits and expectations of each user.

The results regarding their daily usage are as follows:

Table 3 shows the distribution of the participants' ages. Age average: 23.5 (between 17 and 44)

94% had smart phones. The average call per day is 11. (merely by the fact that most physicians and engineers listed almost 20-25 calls). The distribution of daily calls can be seen in Figure 3. And each call lasts an average of 3.7 minutes. It should be noted that these are given by each user's self-

opinion and not their network traffic record. The survey and the opinion test provided an accurate portrayal of self-prediction however, due to most users' prediction coinciding with their actual behaviour. There is a slight deviation with post-disaster behaviour, which can be expected due to certain sociological and psychological aspects like induced fear and panic, but these are not taken into account. Unexpected user behaviour is simulated by users being unaware of the true nature of the test, which gave us more realistic results on the opinion test but the survey weren't based on these aspects.

They spend 7 hours on average online per day as can be seen in Figure 4. 98% are members of at least one form of social network. (Mainly Facebook, Twitter, or LinkedIn) 42% used their phones' video call options yet none use it regularly.

TABLE 3. PARTICIPANTS' AGE DENSITY

Ages	Number of Samples
18-22	17
23-25	13
26-30	19
31-35	6
36-40	3

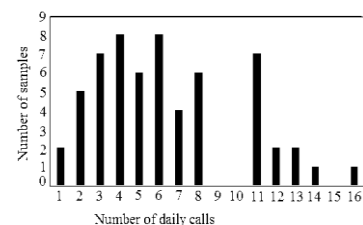


Figure 3. User's number of daily calls

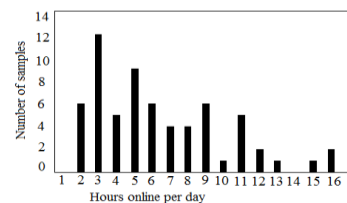


Figure 4. User's number of daily internet usage

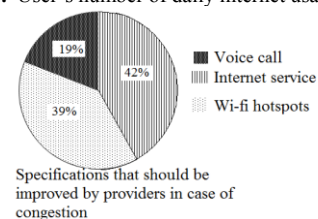


Figure 5. Survey result corresponding to which aspects a provider must improve

As shown in Figure 5, 42% of users want the phone companies to improve internet service while only 19% wish for better voice call options.

Results according to their disaster related behaviour is as follows:

As shown in Figure 6, 26% of the users have never before experienced disaster related congestion while 85% are aware

that network services suffer during disasters. 95% call their relatives or really close friends first while the remaining users call government authorities to get information about the disaster. 76% immediately posts information on their social network about their well-being or local information they have. 94% use voice based web applications regularly, with Skype and Whatsapp being the most popular ones. Immediately after an earthquake, an average user makes 7.5 calls, each lasting an average of 37.5 seconds. During congestion of any kind, almost half of the users are very disturbed by dropped calls and only 13% consider it normal, as shown in Figure 7.

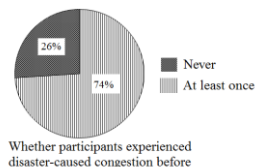


Figure 6. Participants' answer to past disaster experience

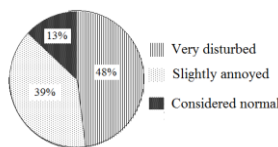


Figure 7. User reaction to dropped calls

Most users (90%) agree that in order to achieve better service, phone companies may limit their call duration, we can see in Figure 8 that the agreed-upon limit being 55-65 seconds per call. Given the option to pay extra per call in order to acquire better service during congestion, 56% if the users are unwilling to pay extra while the rest agrees to pay an average 1.75 US\$ per call. 47% of the users do not agree that network providers should prioritize them according to their past usage of the network and provide service accordingly.

As shown in Figure 9, 43% of users agree on receiving considerably lesser quality voice calls while 25% agrees on limited web accessibility and the remaining 32% agrees that network providers shouldn't limit any of those services. Other suggestion were based on user experiences during past disasters, referring provider's ability to easily inform the clients on the scale of the disaster with SMS messages on a regular basis, with information on survival, dangers and escape routes.

The nature of the online test somehow makes it harder to determine whether the user would act the way as they described, given their situation during disaster times. Although most users already experienced heavy traffic caused congestion in one form or another (during rallies, protests and social gatherings were given as answers) so it can be concluded that given their daily habits and past experiences, most answers can be relied upon to deduct a trustworthy user behaviour prediction.

To reflect that the subjectivity test can be applied to a whole demographic, the age ranges can be compared. Even though it would be understandable that users within this range would be more active both in their calls and their web usage, it is

justified that this demographic creates the most traffic during their daily lives, which would directly affect our given traffic during congestion.

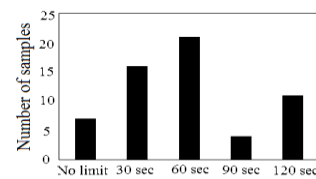


Figure 8. Agreeable call duration limitation

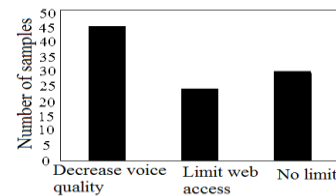


Figure 9. Users' choice on which specifications can be limited during congestion

Our survey clearly shows the necessity of reliable web access during disaster. According to the data, a majority of users spend more than 6 hours daily. More than three quarter gather and upload information about recent events. Most users have smart phones, and almost all of them are members of social networks. Only a handful minority agrees on user priority according to daily usage, even though their usage of network varies greatly, in a sense that even the heavy traffic users are against it. This is due to the fact that users cannot accurately predict the limitations or bonuses that will be granted or deducted in accordance with their account and assume the worst.

It can easily be seen that participants' awareness towards network's potential problems dealing with these issues were actually an issue. It can be said that although not a majority, a great number of users are unaware of the amount of traffic created by their actions and must be informed that they may somehow experience difficulties with their calls, which would not directly affect traffic but possibly contribute to user QoE. It is towards the provider's incentive to warn the users of the slow-down, granted the users may not be aware (shown by the percentage) of the disaster caused traffic.

V. DISCUSSION

According to our results, a majority among the target demographic have access to high speed internet and uses it regularly. A great number of them use social networks to follow daily events and post personal information daily and usually learn daily news from those networks, spending more than 7 hours daily online. In case of a disaster, most users will make 5-6 subsequent calls, each lasting less than a minute, and immediately access the web to post information about themselves and try to learn from others. Voice call options are generally used, however to a lesser extent, which tend to be short and sequential, usually within the first hour of the disaster.

Even after the disaster subsided, users tend to access web continuously, to learn the extent of damage and the well-being

of others. Therefore voice call traffic within the first few hours of the disaster would be continuous and erratic. On the other hand; web access would instead be in smaller chunks of easily manageable data.

Most user agree to pay extra in the guarantee that they get extra service during congestion, the gatherings may well be used for over sourcing or general overhaul of available network over the disaster-prone areas. During the aftermath, web access is a must-have for most users, introducing easily deployed Wi-Fi hotspots can overcome this problem. Due to lots of users communicating through voice based web applications and only returning to voice call during emergencies, communication through web services over the Wi-Fi spots can easily take the burden, and help regulate traffic more efficiently. This option must be focused on since more than two thirds of the users actually rely on a web based voice call during their daily time. Given the internet connection is fast enough, a considerable group of users opt for making online calls and VoIP, due to their ease of use, online capability and social aspects and their reliability, not to mention their being economically better option.

The point given by the opinion score is that given the circumstances, almost all users favour quantity over quality of their calls during the times with high traffic. Yet this hardly affects their perceived QoE on a positive light. Each dropped call had an extreme negative effect on their calls also, so we can assume that even though quality of experience of the network users will lower eventually, with extra amount of regulation of the traffic, it is quite possible to minimize the effects. In our case it would be wiser for more users to connect their calls regardless of quality or waiting times, which would result in better QoE. As we pointed out before, the amount of students and academics in the survey group had a rather positive effect on our prediction map. It has been known that this demographic is the most active and socially able body of users, who are considered tech-savvy and knowledgeable enough to create an active test bed, yet easy enough to take part due to their easy access to social networks and internet know-how. Other occupations and extreme sides of the age group (i.e. much older or younger than average age in the survey) are given special attention however; as their answers, both in awareness and daily habits, gave clues to some rather unexpected behaviour. To give an example, engineers tended to be more active in their voice calls, and doctors having more daily online time. This data would be rather helpful in creating a prediction map of each user's future behaviour if age and occupation can also be taken into account.

Another concern by the providers should be to provide efficient repair services for the damaged infrastructure. Given the fact that mobile teams would be dispatched and Wi-Fi spots and redirected 3g base stations could handle the load for a while, it would be beneficial for phone companies to introduce "emergency sectors" in each base station within the disaster areas, which can easily be manned and operated during the congestion. This can be simply explained as each base station having one more antenna overlooking danger

areas, and quickly installing needed network units in case of disaster striking certain areas, in which case more area can be covered with these new sectors. The proposal of introducing a holding time limit of between 30-40 seconds is of greater importance, since it is the amount of time needed and agreed upon by most users. It would keep the network traffic at a manageable level and have a bigger advantage of users directing their attention towards other forms of connectivity media, over SMS and network messages, which are easier on the bandwidth. More limitation can be introduced proportional to the scale of disaster, keeping in mind that the greater the scale, more users will be aware of it and also affected and traffic would grow exponentially in a smaller time interval.

The idea of user prioritization is considered obsolete for the time being, given how many users were against it. The expected advantage of each user's past usage of the system and their habitual inclination to use a certain system (may it be Wi-Fi spots, SMS etc.) seems to give a rather vague idea of how they would react in a disaster situation, if taken into account only by itself. Although helpful in our future behaviour prediction, this actually means that a user's having spent a lot of time online does not necessarily mean that they will act this way in a congested environment. Rather, it is accepted that their behaviour is taken as a whole, with their online time, calls and their web activity must all contribute to their value as a user and not just their yearly traffic or the provider's monetary gain.

A study based on users' age and occupation taken into account may be proposed, given how actual patterns of these aspects match with a user's habits and their predicted behaviour, i.e. among the samples, students had the most online time while engineers and doctors had more call duration. It may shed light on business practices of a given mobile user and allow the network provider additional benefits.

Projected behaviour after a disaster is less dependent on occupation. With light of this, prioritizing users only according to their yearly usage of the system seems trivial, as long as we can evaluate the patterns of their network usage. Thereby a premium or "gold" user isn't guaranteed to act the same way in a disaster scenario although it contributes to their perceived and therefore predicted behaviour. The concept of introducing premium users in disaster situations is rejected by many survey takers and would no doubt have a negative effect on user QoE. Thereby the idea is shelved for the time being.

Finally, given the advent of social networks, providers can use monetary incentives to allow users to post information regarding their service. To open up hot spots themselves, upload pictures that can help or simply announce vital information to help their peers or the provider. News announced over social networks tend to travel faster than most government agencies' news teams can achieve, which can easily be used in the overall public's favour. It can be seen from our survey that most user who check their social circles for information, tend to also upload information and even

pictures regarding the event, so social networks should not be overlooked for relaying news.

VI. CONCLUSIONS

In this paper, we discussed user behaviour patterns before and after disaster and the congestion caused by it. Introducing a subjectivity test, followed by an online survey; we created a test bed of a great demographic of mobile users and tested their behaviour during normal and disaster situations. We came to the conclusion that during large scale disasters, general mobile users tend to access web services early and often, usually gathering and posting information on social networks. No matter what a user's habits were before, most user act in predetermined patterns and resort to predictable behaviour. If service providers adopt their service model according to the behaviour we discussed, it would be easier and cheaper to accommodate each user the amount of service they need, therefore lessening or even avoiding congestion entirely.

It is assumed that on a disaster scenario, both the users and the network provider is affected similarly, therefore incentives must be taken by both parties to achieve a better result to diminish congestion caused problems. The data gathered from both the survey and the opinion test can be contributed to a much larger demographic, due to it being a rather accurate portrayal of general mobile user, which in turn creates a larger picture of the user base model.

For future work, we plan to simulate a network environment under several disaster scenarios, to test the patterns of user behaviour, and research ways of fighting congestion within these scenarios.

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