User Study on the Feasibility of Incentive Systems for Smartphone-based DTNs in Smart Cities

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ABSTRACT

The idea that devices in a distributed system share their resources is quite old. Recent research areas which continue to rely on this idea are opportunistic networks and participatory sensing. Substantial theoretical work regarding the design of incentive systems intended to encourage and sustain participation in such applications is available: While most of the existing work deals with technical implementations and the question how to make these systems fair and secure, not much thought has been given to the question what an acceptable and economically feasible incentive could be. In this work we implemented an incentive system for a smartphone-based Delay Tolerant Network (DTN) and performed a 1 month study where users tested and evaluated the system. We analysed the users' motives and the sustainability and feasibility of the examined incentive system.

Keywords

User Study; DTN; Incentive System

1. INTRODUCTION

Ever since the idea of ubiquitous computing has been introduced [20] and continued to evolve into the recent Internet-Of-Things meme, it has been clear that one important basic concern for any distributed system is the sharing of resources, such as computational power, storage capacity or network bandwidth. An important aspect of the current situation is, that most of todays ubiquitous devices such as smartphones, tablets, game consoles, NAS devices and of course also the old-fashioned PC, are *personal* devices: They are paid for and used by individuals. So whenever the idea of sharing or donating resources comes up, the first question that needs to be answered is: Why should an individual give away a share of his resources. What is the benefit?

An especially interesting target for sharing communication capabilities are smartphones. Many approaches have been proposed using them to create an ad-hoc network independent of the cellular infrastructure. The vision is that everybody has a smartphone in his pocket which opportunistically connects with other devices in range and exchanges data [9, 19]. Usually, these kind of networks are Delay Tolerant Networks (DTN), which means when there is no suitable communication partner in range, a device will *store* data that needs to be send or forwarded until the next communication opportunity arises. These networks are a good basis for participatory sensing [11, 10] which is becoming increasingly popular within the context of smart city technologies. Other approaches suggest, using smartphone-based networks to offload data from a congested cellular network [5, 2]. To encourage equal participation in such networks, "fair" routing protocols using tit-for-tat strategies [18, 8] have been researched. The systems proposed in [13, 4] show how to securely built an incentive system on top of a DTN. However, in both systems the "incentive" itself is not clearly defined, but rather an abstract token.

The problem with these ideas when applied to smartphone-based networks is, that sharing resources of a smartphone immediately affects battery life. The user experience is negatively impacted. On the other hand, the benefits for users in the aforementioned applications are more insubstantial: "Somehow" a smart city can work better due to the data collected by a phone or "somehow" the network performance increases. But these are not immediate benefits, such as getting desired file from a P2P network.

We think that, despite a solid and secure technical implementation of an incentive system, the question *what* a feasible incentive is, has not yet gotten the attention it deserves, yet it is the most important question when designing an application: *Why* should users support my system? Can I *pay* them enough, or offer sufficient *advantages* to motivate

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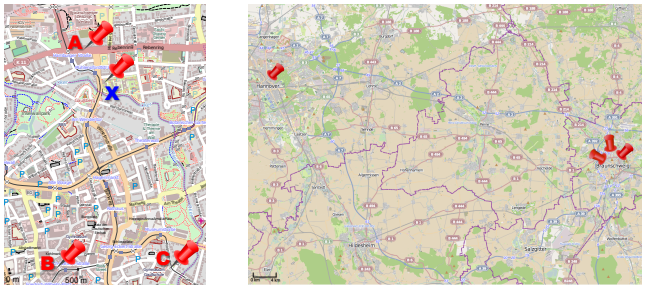

(a) Braunschweig Goals (b) Hannover Bonus Goal

Figure 1: GeoGame Goals

participation? These incentives need to be *economically feasible*. Giving more expensive phones to users for free or even paying them as proposed in [2] probably does not fall into the area of "economically feasible".

In [17] we proposed a system that distributes discount coupons to cooperating participants in a smartphone-based DTN and tries to involve and direct users by offering interesting challenges. While in [17] we showed the economic feasibility of such a system, the contribution of this paper is much more crucial: While it is certainly possible to give a rebate coupon to a user for transporting some data halfway across the city, would people actually do it? We performed an user study to find out whether these rather symbolic rewards would be accepted by users. Instead of just asking people, we set up a demonstration system that required participants to download an application to their mobile phone and reach several separate destinations within a city. We used a questionnaire to analyze what *motivated* the participants to take part in the experiment, to get an insight into how a smartphone-based network needs to be setup to encourage longterm participation of people.

In the remainder of this paper we will introduce the architecture of the implemented system in Section 2 and detail the actual user study in Section 3. After analyzing the evaluation results with special attention to motivational issues in Section 4 we will take a look at related commercial projects in Section 5. Finally, we summarize our findings and give some advices how to design a successful participatory smartphone-based network.

2. THE DTN INCENTIVE SYSTEM

According to [17] we implemented the system as a game. The intention of the game was to send players to different areas with their smartphones or tablets. When enough users can be persuaded to move to specific locations a Smart City application could use the users' mobility and communication abilities to transport data between specific locations It is important to note, that we did not communicate this potential use case to our participants: When starting the game for the first time, the user is informed that he has to reach 3 points, and that upon finishing that task he can fetch a reward consisting of sweets.

For this user study we used only one static set of goals: 3 destinations, distributed within an area of less than 2 km^2 in the city of Braunschweig, needed to be visited by a participant in order to successfully finish the game. The Braunschweig goals are marked with "A" to "C" in Figure 1a. In a DTN asking users to come to a specific place might be done because there are some sensing stations or sinks belonging a Smart City sensing system. Another application might be an electronic billboard system that needs to be updated with new advertisement videos.

(a) A: BS Near University (b) B: BS City Center

(c) C: BS Magni District (d) Hannover Bonus Goal

Figure 2: Goals in Braunschweig (BS) and Hannover (H). Arrows mark the locations of the Wi-Fi access points

After completion of all goals, a participant is asked to come to the institute (location"X") to collect his reward. Additionally, after reaching all 3 goals in Braunschweig and revealing the rewards collection location, the game offers people to double their score by finishing an optional bonus goal. In order to see how far people would go, and to make sure the effort cannot rationally be justified by the reward the bonus goal was located in another city, Hannover, about 60 km away from Braunschweig (see Figure 1b). The bonus goal was located in a business area (see Figure 2d) in walking distance from Hannover main train station.

All 3 Braunschweig goals are known when an user starts the game, so it is possible to finish them in any order. We placed the goals in such away that they are easy to reach. Point "A" (Figure 2a) is located directly besides the university main campus near the city center. Point "B" (Figure 2b) is inside the city center and point "C" (Figure 2c) is located in a historic district near the center. Except the 1 month playing period of the experiment there is no time-limit. We made sure the reward could be gathered anytime during normal working days.

2.1 User Interaction

In our implementation we made the decision to make all interaction with the system explicit. Many projects proposing smartphone-based networks assume that the necessary software will run in the background all the time, scanning for possible contacts and autonomously exchanging data. While

Figure 3: Android GUI on a 10" tablet and a 3.8" phone

this is a conceptually nice idea, the last decade has shown that the technology is not quite there (yet): Operating in such a way has tremendous impact on battery life as there is no technology which allows continuous energy efficient scanning for neighbors. Beacons need to be send and received. Both operations are expensive with any RF technology. Simple duty-cycling methods have been researched, where the receivers know at which time to expect a beacon. In many practical scenarios this is unfeasible, as it requires strict time synchronization between all nodes. Special schedules have been proposed to overcome this limitation and allow for asynchronous discovery even if nodes are duty-cycling their radios [6, 1].

However, while such approaches can reduce the energy spent for discovery, energy usage is still significant. Additionally in the common case of using Wi-Fi enabled devices such as smartphones, a practical implementation hurdle for duty-cycling approaches is the long and device-dependent time to bring the Wi-Fi interface up and down [1].

With the incentive system implemented for this user study this is not a problem, as the concept adapted for this study is designed to involve the user by offering challenges to him. For this usecase an application running silently in the background would be rather counter-productive. Instead, the design demands users' to consciously move to the required places. Once near a goal, the user has to open the application to complete that goal. Only when opened and in foreground the app will acquire the current location and scan for a base station. Energy will only be used if the user actively uses the app. This makes the impact on battery life more predictable and keeps the control over a device completely in the user's hand. Of course, this design precludes opportunistic device-to-device contacts but one can argue that this does not matter much, as a smartphone-based network is inherently a DTN network. Therefore, the added delay due to potentially unused device-to-device contacts should not be a problem for applications running on such a network. Also, this effect is offset by the fact, that with such a game-based approach participants can actually be *directed* to some degree, which improves network performance.

Figure 4: PI base station at goal A

2.2 Android Application

The game which, we called "GeoGame", has been implemented on Android. This is a sensible choice for scenarios where an opportunistic networking platform or a smart city application aims to leverage the capabilities of private mobile devices. We put considerable effort into making the application as streamlined and intuitive as possible, in order to provide an user experience that is as close as possible to a fully functional deployed commercial system. Careful design and testing made sure, that the UI is workable on the smallest mobile phone screens as well as on full size tablets (see Figure 3). The main part of the screen is the map, which shows the user's position and possible next targets.

When starting the game for the first time, or when completing a goal, the user is informed by a message that will suggest possible next steps. Once a user has finished all goals and comes to the reward collection point, a slide show will lead him to the exact office within the university building.

2.3 Base Stations

For this user study we also needed to implement the base station. While we could just have used the location abilities of a smartphone to simulate the effect of reaching a DTN router, doing so would have altered the user experience. Our base stations provide Wi-Fi access points. Just as in a real deployment, the mobile application needs to detect whether it is in the vicinity of a base station, and then associate to the appropriate Wi-Fi network and begin exchanging data. This is the same procedure that would happen in a real DTN system and makes the user study more realistic in terms of reliability and latency when connecting to the base stations. Tests have shown, that the whole process of connecting to base station and exchanging some information through a TLS connection can take up to 20 seconds.

We used RaspberryPI SBCs[1] as base stations. A PI is a low powered ARM systems running a standard Linux operating system. A Wi-Fi interface was attached via USB. The whole system could be powered by a standard micro USB mobile phone power adapter. This hardware costs significantly less than 100 EUR and meets the cost efficiency of the solution proposed in [17]. While in a real scenario the PIs could also represent DTN sources with no Internet con-

[1] `http://www.raspberrypi.org`

Figure 5: GeoGame website

nection, for the user study we connected all PIs to the Internet to make monitoring and maintenance of the experiment easier. The PIs have been deployed in residential homes or offices. A typical installation can be seen in Figure 4.

The PIs connect to a central database server. Whenever a mobile phone connected with a PI, this was reported to the backend. This information could later be used to check whether a person collecting the reward was really eligible. In a deployed DTN application a cryptographic token would be given to devices as proof of reaching a certain goal [17]. In the user study the centralized approach made managing the system much easier, without altering the user experience. Only anonymous Android IDs have been used to identify participants. No personal data have been transmitted and all collected data have been deleted after the conclusion of the user study.

3. USER STUDY

The user study started on June 24th and ran until July 26th 2013.

3.1 Campaigning

One of the hardest parts of any user study is getting enough participants. As it was already clear that we would not be able to do a large-scale experiment, with a participant group that is representative of the whole German population, we focused our marketing efforts around the university. A small 2-page flyer with some basic information about the game was created. The flyer explains, that reaching certain locations with a smartphone would earn the player a reward in the form of sweets. It does not mention that this is part of an user-study or that there will be a questionnaire to avoid biasing participants. Additionally, during the campaign there was a GeoGame website (see Figure 5), that informed about the game and published news using a Twitter account.

The flyers have been distributed during the yearly "TU Night" event where the university presents itself to interested citizens with a whole night of information and entertainment programmes. This was also a chance to reach out to persons outside the university. During the campaign we continued to deposit the flyers daily at one of the university's canteens. Early during the campaign the social-media team of Braunschweig noticed the experiment and posted some information on the city's official Facebook profile.

During the 1-month playing period the application has been installed on 219 different devices. Figure 6 shows, how the number of installs goes up at the beginning of the campaign, reaches a maximum in the middle of July and then starts to decrease. This shows that most participants have been convinced in the first part of the campaign, while in the later part people who finished the game uninstalled it.

3.2 Privacy Protection

No personal data have been collected during the experiment. Due to the nature of the game we needed access to the devices' location stack and a unique identifier for each device, to track the game's progress. The device identifier can not be connected to a particular person and any data generated during the game has never been transmitted to us, except the device id when a participant connected to a base station. When downloading the application from the Google Play Store, the description provided informed participants in detail, which permissions the application requires and what those permissions have been used for. After conducting the study all collected data from the application have been deleted.

3.3 Questionnaire

All participants who completed the final goal and came to collect their reward, had been asked to fill a PC-based questionnaire. During the process of filling the questionnaire a participant will receive his actual reward. For efficiency, when possible questions are multiple choice, or use Likert scales[12] when asking questions of degree (e.g. "How important was the reward? - Very important/important/not very important/not important"). The questionnaire consists of 8 parts that aim to highlight different aspects of the system.

General Questions: General information such as age, gender or professional position are gathered in the first part. This demographic data can help to put other collected data into perspective.

Smartphone Usage and Familiarity: We collected information about the intensity with which a participant uses his smartphone and whether he already has knowledge about or interest in other location based apps.

GeoGame App Experience: We asked, whether there have been any specific technical problems or usability issues with the GeoGame app. Implementation-specific problems are unrelated to the type of system we wanted to evaluate and could bias the results.

Difficulty: We measured the perceived difficulty of reaching the goals in the game. This part also includes questions about the mode of transportation used to reach a goal and the familiarity of the participant with the game area.

Optional Bonus Goal: This part deals specifically with the bonus goal in Hannover. We asked for the reasons why a participant chose to complete the bonus goal or not. Data about the mode of transportation to reach the bonus goal has also been collected.

Trust: As collecting potentially personal information is a sensitive topic, especially in Germany, we added a block the questionnaire that assesses whether participants were convinced, that the application did not collect personal in-

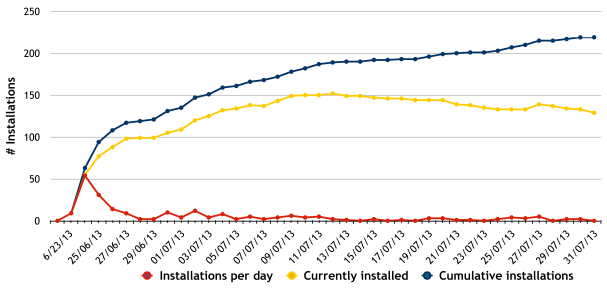

Figure 6: GeoGame installs over time

formation (it did not). We wanted to see, whether - or for what reasons - users trust the application or not.

Reward: Before starting this part of the questionnaire a participant gets his reward in the form of sweets. He could take as much as he wanted (see Section 4.7). The amount in grams is put into the questionnaire. We asked, whether the user considers the reward an important aspect of the game or not. We also checked whether participants are happy with their reward or whether they would have preferred something else.

Intrinsic and Extrinsic Motivation: Obviously, we could motivate participants who filled the questionnaire to play and finish the game. It is very important to understand, what the source of this motivation was. *Intrinsic* motivation basically means, a participant is motivated by the task itself while purely *extrinsic* motivation means, he is motivated by external influences. For the examined system intrinsic motivation would be the more sustainable one, as keeping extrinsic motivation up could be quite costly in the longterm (see Section 4.8).

4. EVALUATION

The official playing phase for the GeoGame ran from June 24th until the 26th of July. After that date the application was pulled from the Google Play Store, but we gave players who already started the game a chance to finish it until the 1st of August. This extension was communicated by the application starting one week before the official end of the experiment.

In total the GeoGame has been installed on 219 different devices. 72 devices (32.9%) completed at least one of the goals. This already shows, that there are a lot of people, who were willing to install the game, but probably immediately forgot about it. 48 (21.9 %) persons completed all 3 Braunschweig goals, which is a pretty good conversion rate from the 219 initial installs. This is also the relevant number for any deployed system that aims to leverage volunteers to transport data in a DTN. For this user study it was required that participants come to our institute at predefined times to get their reward and do the questionnaire. 31 persons did that (64.8% of the people who finished the game).

As we only gathered information from people installing and finishing the game, the results presented here do not provide any direct insight as to why some persons did not play or finish the game. However, as we will see, some ideas can be extrapolated from the answers of the finishing participants. Also, the amount of persons downloading and starting to play the game shows, that in principle it is possible to gather enough initial interest for deploying a feasible DTN system.

4.1 Demographics

Persons between 21 and 77 years completed the questionnaire. The average age was 29.5 years (median 26 years). 77.4% of the participants have been male and 22.6% female. As expected, most participants where associated with the university: We got 51.6% students and 32.3% research staff.

4.2 Smartphone Usage and Familiarity

We asked abut the general proficiency of users with smartphones and location based applications. 58.1% of the participants said they "always" have their smartphones with them, and another 29% answered they carry their smartphone "most of the time" This is in line with other studies: A survey conducted 2013 in Germany concluded that 75% off all citizens never leave their homes without a mobile phone[3].

We also checked, whether our participants had already an interest in location-based applications. The general question about the interest in location-based applications was rather inconclusive: 22.6% reported a "strong" interest, 45.2% a "moderate" interest, 25.8% "little" and 6.5% "no" interest. We also asked specifically about Geocaching, which is pretty popular in Germany. Only 6.5% of the participants said that they regularly hunt for caches. However, the remaining 93.5% have either tried Geocaching once or at least heard about it. This shows that our group was not particularly biased towards location-based games, but also that the concept is already well-known.

4.3 GeoGame Application Experience

We asked, how well the GeoGame app worked and what the user experience was. As the goal was to evaluate the feasibility of smartphone based DTN *concept*, we needed to make sure, the results are not biased by a bad implementation. Users were asked to use the German school grading system (1.0 for outstanding to 5.0 for insufficient) to rate the application. It scored a solid 1.6 for usability and 1.8 for functionality. The only problem mentioned to us, have been occasional GPS location difficulties on some devices.

4.4 Difficulty

80.6% percent of the participants judged their familiarity with the city as "good" or "very good". 96.8% agreed that reaching the goals has been "easy" or "very easy". We asked, which mode of transportation was used to reach the goals. Multiple answers could be chosen. A majority of people said they walked to the destinations (58.1%) or they used the bike (48.4%). Regarding the goals in Braunschweig 71% of the participants are near the university goal "daily" or "often", while for the goal in the Magni district this is only true for 25.9%. This is in line with the fact that most participants were university students or staff. Only one person said that he is "often" near the bonus goal in Hannover.

4.5 Bonus Goal

While we were not sure, whether anyone would go 60 km to the bonus goal in Hannover, in fact 4 out of 31 (12.9%) players did go there. This is interesting, since only one participant (who did not complete the Hannover Bonus goal)

claimed that he is often near that point. From the information available to participants before the game, it should have been quite clear, that despite the promised reward, going to Hannover for the sake of the game alone would probably not make any economic sense.

We asked the reasons for skipping or finishing the bonus point. Multiple answers have been possible. The main reasons for people not going to the bonus goal were "too much distance" (71%) or "not enough time" (45%). 2 persons said they did not feel like it, and the game was not entertaining enough. Of the 4 persons who finished the bonus goal all said they did it because they "wanted to". Two added they also did it, because they wanted to double their reward. Remember, that after completing the 3 goals in Braunschweig, the application offered participants to finish the bonus goal to double their reward. As we asked everybody to choose as much sweets as they deemed *appropriate* (see Section 4.7), it would have been up to the participants to double their own reward. None of the 4 participants completing the Hannover goal lived in Hannover or had chosen the option "Because I am regularly in Hannover".

These results already give a first strong indication, that weighing the actual effort against the reward in a purely economic way is not the main motivation to reach the goals.

4.6 Trust

It is common knowledge that many applications and services invade the privacy of their customers. Fear of being spied on, or sharing valuable private data, can be prime concern for not adopting a new application or service. For this experiment it is important to note, that the user study falls directly in the time when the first Snowden documents regarding PRISM came up[15]. While in June it was still a non-topic in the US, in Germany it dominated media and public discussion very fast. Therefore, the results here might change if the study is repeated.

We asked, whether the participants believed that the GeoGame did not collect any personal data (which it did not). 54.8% believed that claim, which means 45.2% were unsure or did not believe it. This shows a certain awareness for the problem, but maybe also some sort of resignation, since almost half of the people were not convinced that no data was collected, but still participated in the experiment.

We asked participants who were unsure regarding the claims that no personal data has been collected, what factors would inspire the most trust in an application or its creators. The first choice was "A renowned magazine reports about it" (29 %) followed by "Many people use it" (9.7%).

4.7 Reward

After answering all previous sections there was a break in the questionnaire, where a participant gets his or her reward. Keep in mind that regarding the rewards there have been two related goals in this study: Will people accept and be happy with an (economically feasible) reward, such as sweets? and also what kind of reward and what amount would participants deem reasonable? This implies, we need to choose a reward *we* thought of being sufficient prior to the study. To get a clearer view what is acceptable by participants, and to avoid misjudging the appropriate amount, we adopted the following strategy: A full bowl of sweets and candy (see Figure 7) is presented and the participant is instructed to "take as much as is appropriate for finishing the game". The instructor would not say anything more. An interesting pattern emerged: A majority of people would first grab the whole bowl with a remark like "Ok then... as much as I want huh?". But in all those cases, without any intervention on part of the instructor, the participant would put the bowl down and choose some amount. To our surprise, people really did not take much. Even though offered the opportunity to fully compensate their perceived costs, the average amount of sweets grabbed was $61.65g \pm 47g$. The largest amount was $201g$. We noticed, that many people tried to rationalize their choice like "3 goals, 3 pieces".

Figure 7: The reward bowl

This indicates, that rather small rewards might be enough to support a volunteer-driven DTN. However, we also asked how happy participants have been with their reward. While 41.9% considered themselves "very happy", 38.7% considered themselves only "somewhat happy", and the remaining 19.4% give even lower scores. This shows, that despite the fact, that people where free to choose the amount of sweets, when asked directly some also felt that it was probably not appropriate or enough considering their effort. This may interpreted in such a way, that physical rewards may not be the right choice to support such as system. With a physical thing of concrete value it is always easily possible to rationally weigh the profit against the investment.

We asked which kind of reward participants would prefer. The options were "coupons", "money", "sweets" or "others" (with a free text field to specify). Only 14.3% have chosen "money". Noteworthy recurring mentions in the "others" category have been "leader boards", "achievements" and "more entertainment/story in the game". So even when given the ability to freely choose some substantial reward it seems, many participants think virtual goods are enough or even more appropriate *and* desirable. This also shows that people accepted even the rather barebone GeoGame as a *game* and despite the fact that a reward was promised at the beginning did not view it as some kind of service they need to be paid for. This idea can be substantiated when we compare the questions "How important was the reward?" vs. "How important was it to reach the goals?" as can be seen in Figure 8.

These results indicate, that a community supported smartphone-based DTN network can actually be deployed and operated economically. To get some more information whether this would be viable in the long term, we look at the results from determining the motivation of participants in the following Section.

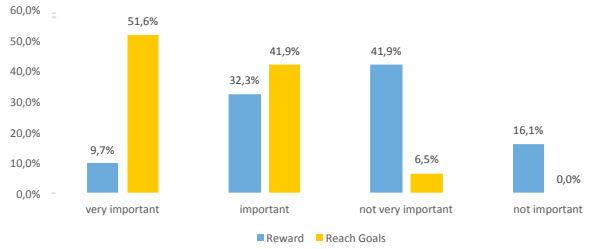

Figure 8: Importance of rewards vs. achieving goals

4.8 Intrinsic and Extrinsic Motivation

Relying on smartphone users to form a DTN is technically possible. The question, whether it is feasible and sustainable depends on the *motivation* of the participants. There are many criteria and classifications for motivation. Most important for this user study is the difference between *intrinsic* and *extrinsic* motivation [16].

If somebody is intrinsically motivated to do something, he does it for the enjoyment gathered from the action itself. For example, studying something, purely because it is interesting. Conversely, if somebody is extrinsically motivated to do something, he performs an action as a means to an end: For example, studying something solely to get a good grade. The outcome is separated from the action itself. The desired goal is to get a good grade. One will do whatever necessary to reach the goals with an appropriate, preferably minimal, effort. Often the employee in an employer-employee relationship is another prime example for extrinsic motivation.

This simple taxonomy of extrinsic motivation is extended by Self-Determination Theory (SDT) [7]. One can make a distinction, how internalized the causes for a motivation are. In this study we differentiate between *externally regulated behavior*, which is equivalent to the example of extrinsic motivated behavior above: A reward (or fear of punishment) is the reason for doing something, the controlling factor is perceived as external by the acting individual. Another case is *identified regulation* or the even stronger *integrated regulation*, where the cause of motivation is still external, but conducting an action or behaving in a certain way is considered to be of *personal importance*. The reasons for doing something are at least partially perceived as internal. An example where motivations are internalized, are social and cultural conventions encouraging a certain behavior. Finally, there is also *Amotivation*, if somebody is not compelled, neither by external nor internal forces, to do something.

For the system examined in this user study intrinsic or at least internalized motivation is preferable, because it is clearly needed to make the system economically feasible. With externally regulated extrinsic motivation, people would compare the reward with their effort and desire a payment that they feel covers their costs. Just considering the traveling distance needed to reach the 3 Braunschweig goals and the minimum time, which is around 15 min, would demand an reward equal to several EUR when basing the calculation on transportation fees and a minimum wage for the time needed. Some amount of intrinsic of internalized motivation is needed to be able to motivate enough data carriers at a feasible cost.

In this part of the questionnaire in total there have been 16 statements where participants can choose their degree of agreement on a 6 point Likert scale. The statements can be classified into 4 categories: Agreement with 4 statements indicates intrinsic motivation. 3 statements represent identified or integrated regulation, which is still an usable source of motivation for the system. 3 statements describing external regulation and 4 statements describing amotivation are problematic: If the majority of participants would exhibit a stronger agreement with those statements, it means that the studied system would not be able to operate sustainably. 2 statements have been assigned to the aforementioned classes after correlation of the answers to the a-priori classified statements. One of those falls into the intrinsic class while the other was correlated with external motivation. When coding the Lickert scale from 6 points for strong agreement to 1 point for disagreement the results of the answers to this question block are as shown in Table 1.

The percentage row in Table 1 makes it easer to compare the classes: To get 100% for a given class, a participant would need to chose the highest rating on the Likert scale for all statements belonging to that class. It can be seen, that the average participant is 73% intrinsically motivated, which is an encouraging result. External or amotivation tendencies are both at 44%. When comparing the desirables causes for motivation (intrinisc to identifed) with the unsustainable ones (external or amotivated) we can see, that on average the desirable causes beat the unsustainable ones by 65% to 43%. This can be interpreted as proof, that a volunteer-driven smartphone-based DTN system could work. The results are especially good, considering the implemented system was rather barebone an did not contain any advanced, and exciting challenges like those mentioned in [17]. The amotivation tendency is larger than we expected. From the answers we assume there have been a number people who just played the game to help with our study without taking any real interest in it. That in this section they ended up in the amotivation instead of the external class or not at all due to not finishing the game can be seen as an indication, that the challenges posed by the game have been rather simple.

4.9 Out-Of-Band Answers

Apart from the questionnaire people have talked to us during the playing phase or after the questionnaire. Other people have used the unrestricted text fields of the questionnaire to put some additional thoughts. In this Section we want to mention some of the things, which came up.

It became immediately clear, that despite the rather barebone presentation people primarily enjoyed the gameplay aspects of the study. Repeatedly, a central highscore list or leaderboards have been mentioned as improvement to the system. This is also illustrated by another “incident”: Shortly after the game phase started, we made a post on Twitter, that a player reached all goals within 16 minutes. At that point our intention was just to make the Twitter feed more interesting. Keep in mind, since we did not have any data about the players, the post could not even mention any name or nickname, but merely stated “a player”. However, around one week later a participant turned up for his reward and questionnaire and asked about his time, because he was pretty sure his time must have been faster, but he was disappointed that did not see a Twitter post about it.

	Intrinsic (A)	Identified (B)	External (C)	Amotivation (D)	**Sustainable (A+B)**	**Unsustainable (C+D)**
Average	17.65 ± 4.22	9.71 ± 3.59	7.94 ± 3.31	10.45 ± 5.10	27.35 ± 7.07	18.38 ± 6.80
Median	18.0	11.0	7.0	9.0	29.0	18.0
Percentage	73%	54%	44%	44%	65%	43%

Table 1: Participants motivation

It turned out his time was indeed faster (14 minutes). This highlighted an exploitable element of competition which we did not anticipate.

Another participant mentioned, that he was able catch the university point (see Figure 2a) in Braunschweig while driving past it with his car. This point might be worth considering by people designing VANET applications: By choosing locations accordingly, these kind of games could provide some sorely needed applications and additional benefit for early adopters of VANET technology. Currently the industry faces the chicken-and-egg problem, that most VANET scenarios related to traffic and safety only work well, once a high market penetration has been reached. However, putting out some stations for a GeoGame-like entertainment application in some metropolitan areas would be pretty cheap for car manufacturers while at the same time it would be immediately usable by any equipped car. This is in contrast to other envisioned VANET applications that have the chicken-and-egg problem of relying on a high density of suitably equipped cars.

Repeatedly, people mentioned, that they would play again, but only if the task is varied. Mostly people had no interest to walk to the exact same locations again, but with another set of locations or a varied task, such as time pressure, many people said they would play again.

4.10 Limitations

There are some limitations in this study. As it only includes a limited of number of people the results are not representative. Due to the variance and conclusiveness of the answers we are however quite sure that this study disclosed some tendencies which would also hold up in a large-scale experiment. A problem is that the participant group was largely centered around university (see Section 4.1), and therefore the results only apply to this group. However, when implementing an incentive-based DTN system it is not important that *everybody* can be motivated to support it, but rather that *enough* people support it. Therefore, we can conclude that the demographic represented by university staff and students is a good target for such a system. Furthermore, the participants from outside the university context, provided basically the same answers as the university-related participants. Hence we have some confidence, that the tendencies identified by this study are generally applicable.

There is one question which any user study like this can not completely answer: For many participants it might have been interesting to play because of the novelty of the game. What is really needed to keep that interest up can not directly be derived from this user study, although as we got some pointers from the received answers: Participants expect themselves to have continued interest, should varying and interesting tasks or more competitive elements be offered.

5. RELATED PRODUCTS

While in the introduction we looked at some related research challenges in the scientific community, we also want to mention some related commercial projects. A comparable user experience is provided by SCVNGR[2], a startup offering location-based social games quite similar to the challenges of the GeoGame. A web frontend can be used to create challenges, sending people to locations where they can be asked to solve various questions. While virtually nonexistent in Europe, the application is more widespread in North America. The company has acquired some venture capital and tries to sell the service to businesses for marketing or universities offering orientation rallies. SCVNGR is purely GPS-based, so that in its current form it cannot support any form of networking. One of the most successful location-based games is the relatively new Ingress[3] from Google. Ingress is an augmented reality game, where members of two different factions need to physically visit so called "portals", which usually are landmarks, to gain control over them. Even though Ingress only transitioned out of a semi-closed beta phase to an open beta in October of 2013, it has already gathered players from all over the world. An unofficial community-driven study about Ingress players is available at [14], but unfortunately it did not ask directly what motivates players to play. In summer 2013 Google started experimenting with advertisement, by putting "portals" into the venues of advertisement partners.

We do not know, whether those companies ever did some not published studies analyzing the motives of their users. However, these examples underline the results of this study: Providing an entertaining game can provide enough incentive to keep users moving between arbitrary locations with their phones. While SVNGR as well as Ingress have started trying to make money based on advertisements, the potential of a DTN network provided by the players has not been tapped so far. Theoretically, both system could be extended easily to support the style of networking proposed in this paper.

6. CONCLUSIONS

In this study we implemented a system that mimics a smartphone-based DTN network. While these kind of networks have often been proposed in literature, we focus on the question whether it is actually a reasonable assumption that normal users transport data for an arbitrary system. We decoupled the actual data that could be transported by the system from the application a user sees. A game is offered to encourage people to carry data that might be totally unrelated to the game.

We performed a user study to find out, if users can be motivated to participate in such a system. We analyzed

[2] `http://www.scvngr.com`
[3] `http://www.ingress.com`

whether small, economically feasible incentives can inspire participation in such a system, and what kind of motivation drives users to get an idea whether such a system would be sustainable in the long-term. Our study showed several things: A material reward, while appreciated, is neither expected nor desired. Many people suggested virtual rewards such as highscores or leader boards. Experiencing the system primarily as a game, also implies people expecting *continuous entertainment*. Only with new tasks, goals or achievements is it likely that people would continue to play.

Even when using the simple user study application, participants are mostly internally motivated, which is a good thing, as it is hard to imagine a smartphone DTN network to be economically sustainable if people need to be literally paid. Overall, this study seems to support the view that "gamification" is a powerful way to engage users. This would suggest, that existing location-based games such as Ingress could be piggy-backed to transport data. The important advice is: Entertainment first. Leave the classical tit-for-tat strategies, that worked fine for P2P file sharing networks, behind you. Instead of trying to sell people on the services the DTN network provides (which they might or might not need), provide them with the entertainment (and sell the resulting network capacity independently).

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