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RADIO SCIENCE FOR HUMANITY

Spreading the Traffic Load in Emergency Ad-Hoc Networks deployed by Drone Mounted Base Stations

Diffuser la charge du trafic dans des réseaux d'urgence ad-hoc par des stations de base montées sur drones

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Abstract:
Today's wireless networks are very reliable but in emergency scenarios they can quickly become saturated. One way to provide a temporary solution is to mount femtocell base stations on drones. In this study, we investigate if the number of required drones can be reduced by equipping public transport and emergency services vehicles with a femtocell base station. To this end, a network planning tool for the drones has been developed while accounting for the coverage already provided by the base stations installed in public transport and emergency services vehicles. The tool has been applied on a realistic disaster scenario in the city center of Ghent, Belgium. Our results show that the amount of traffic of the drone mounted base stations can be reduced. As using emergency services and public transport vehicles enables to reconnect 5% of all users. This limited influence is due to the less optimal location of the vehicles. Still 3205 drones are required to cover all users.

Résumé:
Les réseaux sans fil d'aujourd'hui sont très fiables, mais peuvent rapidement devenir saturé dans des scénarios d'urgence. L'une des façons de fournir une solution temporaire à ce problème consiste à monter des stations de base femtocell sur des drones. Nous examinons, dans cette étude, la possibilité de réduire le nombre de drones requis en équipant les véhicules du transport en commun et des services d'urgence d'une station de base femtocell. À cette fin, un outil de planification de réseau pour les drones a été élaboré en prenant en compte la couverture déjà fournis par les stations de base installées dans les véhicules. L'outil a été appliqué sur un scénario de catastrophe réaliste dans le centre-ville de Gand, Belgique. Nos résultats montrent que la quantité du trafic émanant des stations de base montées sur les drones peut être réduit. Toutefois, l'utilisation des véhicules ne permet de reconnecter que 5% de tous les utilisateurs. Cette limitation dans est due à l'emplacement, jugé moins optimal, des véhicules. Finalement, il faut compter encore 3205 drones pour assurer une couverture de tous les utilisateurs.

1 Introduction

Today, our wireless access networks are very reliable. This connectivity has become a natural thing and it is logical that in case of an emergency, we want to get in touch with our loved ones. However, this might not be possible due to saturation of the network. In August 2011, the annual music festival Pukkelpop (Kiewit, Belgium), with 60.000 attendees was hit by a severe storm causing 140 injuries and even 5 deaths. The news about the storm quickly reached the media, and the network was saturated by people trying to get in touch with each other. More recently, in March 2016, Brussels got hit by a terror attack. The network was not only saturated in Brussels, but also in big parts of the country phone calls were no longer possible. One way to offer a solution for this problem is to mount base stations on unmanned aerial vehicles (UAVs) like hot air balloons or drones.
In [1], we showed the potential of mounting an LTE (Long Term Evolution) femtocell base station on drones to offer a solution for this kind of scenarios. Although the use of drones is a promising scenario to investigate, one of the drawbacks is the amount of required drones. The cost of acquiring and maintaining high amounts of drones is highly depended on the used type. Here, we investigate the possibility to reduce the amount of drones by using femtocell base stations installed in emergency services vehicles and the public transport like buses and taxis. To this end, a deployment tool for drone based emergency ad-hoc networks is proposed, accounting for

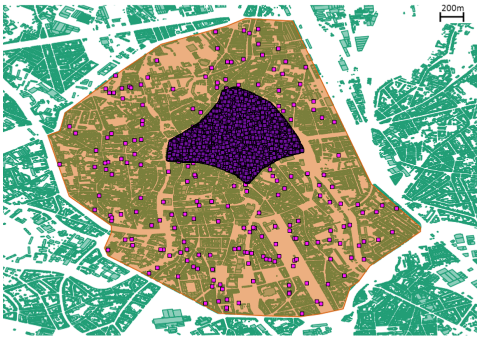

Figure 1: The user locations in the assumed disaster area (6.85 km^2) in Ghent, Belgium.

the user coverage provided by the base stations installed in the public transport and emergency service vehicles. The tool will be applied on a realistic disaster scenario in the city center of Ghent, Belgium.
The outline of the paper is as follows. In Section 2, we discuss the considered scenario and the deployment tool. Section 3 shows the results obtained with the tool for the realistic disaster scenario. In Section 4, we summarize the most important conclusions obtained from this study.

2 Methodology

2.1 Scenario

As scenario we assume 'De Gentse Feesten' which is an annual festival with many stages and activities throughout the heart of the city of Ghent (Belgium). Fig. 1 shows the considered area together with the locations of the users in the area that needs to be reconnected. In the heart of the city, we have 50.000 festival users [2], while throughout the whole city (6.85 km^2) we have 224 residential users which might not be attending the festival [3], but also have lost their connection. A 3D map of this suburban outdoor area gives all information about the location of the buildings in the environment, as well as their shape and their height, in the form of a shape file. Based on this information, the deployment tool can decide whether or not a user is indoor and is in Line-of-Sight (LoS) of a certain base station.
We will investigate if it is possible to reconnect people by installing femtocell base stations on drones, in emergency service vehicles, and in the vehicles (busses and taxis) of the public transport. A femtocell base station was chosen because of its small size and limited power consumption (i.e., 12 W) [4]. As technology LTE (Long Term Evolution) is assumed and all relevant link budget parameters can be found in Table 2 [1]. The path loss model here considered is the Walfish-Ikegami model [5].
Table 3 shows all other assumptions for the scenario besides the link budget. For the users, two bit rates are considered: 64 kbps for voice calls and 1 Mbps for data calls. These values are based on data provided by a Belgian operator [3]. Considering the amount of vehicle carriers and the locations of their stations and stops, real data from the city of Ghent and its public transportation was used. For the emergency service vehicles, a range around the disaster is assumed. Within this range, the emergency service vehicles will be uniformly distrubuted. Outside this range, no emergency vehicle will be stationed. Furthermore, it will only be possible to connect to a femtocell base station when it is not moving. Therefore, we also have to account for the chance that a bus or taxi is not located at a stop when the emergency occurs. Similarly when an emergency service vehicle leaves the disaster scene before the end of the intervention, it will not be possible to use it to serve users. For the drone carrier, an off-the-shelf type of drone was assumed [1]. Finally, a worst-case scenario (high amount of people) is proposed and thus none of the existing (fixed) infrastructure can be used to connect users. The results presented in this paper are obtained after 40 simulations.

2.2 Deployment tool

Fig. 4 shows the different steps of the proposed algorithm. As can be seen in Fig. 4, the algorithm consists of two major steps. In the first step, we will try to cover the residential users, while in the second step, we will try to reconnect the festival users. The approach for both types of users is the same. First, we will try to reconnect the users by using the base stations installed in the emergency service vehicles. If there are still uncovered users, the base stations installed in the public transport (buses and taxis) vehicles will be used. If there are still any uncovered users, we will try to cover these users by using drones. The drones are considered as last carrier since this is also the most expensive solution. To determine which users can be covered by the femtocell base stations installed in emergency service and public transport vehicles, the same algorithm as in [3] is used. The list of possible base station locations is here replaced by the locations of the emergency service and public transport

Parameter	**Value**
Frequency	2600 MHz
Maximum input power BS antenna	33 dBm
Antenna gain BS	4 dBi
Soft handover gain	0 dB
Feeder loss BS	0 dB
Fade margin	10 dB
Interference margin	2 dB
Receiver SNR (Signal-to-Noise Ratio)	1/3 QPSK = -1.5 dB 1/2 QPSK = 3 dB 2/3 QPSK = 10.5 dB 1/2 16-QAM = 14 dB 2/3 16-QAM = 19 dB 1/2 64-QAM = 23 dB 2/3 64-QAM = 29.4 dB
Bandwidth	5 MHz
Number of used subcarriers	301
Total number of subcarriers	512
Noise figure mobile station	8 dB
Implementation loss mobile station	0 dB
Shadowing margin	12.3 dB
MIMO gain	0 dB (1x1 SISO)

Table 2: Link budget parameters for the LTE femtocell base station [1].

Parameter	**Value**
Bit rate users	64 kbps for voice 1 Mbps for data
Duration intervention	4h
Bus stations	5
Available buses	53
Chance a bus is present at a stop	50%
Taxi stations	22
Available taxis	110
Chance a taxi is present at a stop	30%
Available emergency service vehicles	40
Chance an emergency service vehicle leaves	60%
Range disaster	300m
Maximum height drone	150m
Speed of drone	12/ms
Power of drone	13 A
Power usage of drone	17.33 Ah
Battery voltage of drone	22.2 V
Available existing infrastructure	0%

Table 3: Parameter assumptions used for the considered scenarios.

vehicles. The general idea behind this algorithm is to connect each user to an already active base station from which the user experiences the lowest path loss (and lower than the maximum allowable path loss) and can still offer the bit rate required by the user. In case no active base station fits these requirements, a new base station will be turned on if possible. To determine the amount of needed drones and their coverage, the algorithm proposed in [1] is used. This algorithm first generates a list of all possible base station locations by placing a drone above every user. To connect all users to the different base station locations, the same general idea as mentioned above is applied. However, the algorithm has one additional step which accounts for the amount of available drones. The drones will be assigned to these locations that serve the highest number of users.

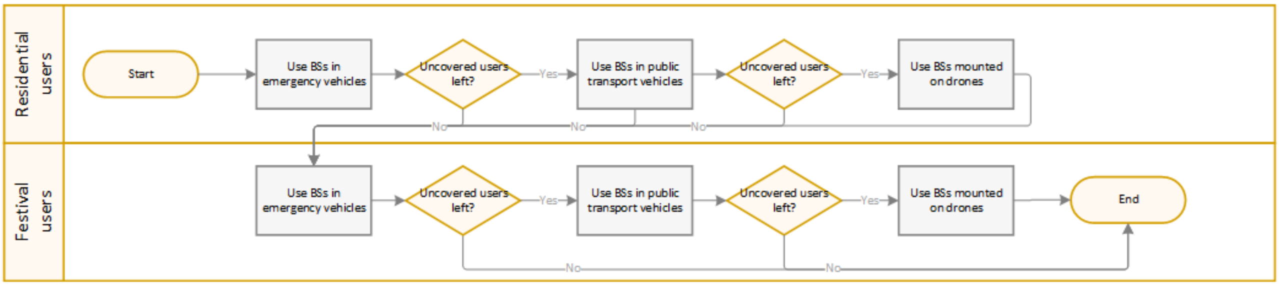

Figure 4: Flow diagram of the algorithm.

3 Results

Fig. 5 shows the different locations of the base stations (independent on the carrier) obtained with the deployment tool. To cover all the residential users, the following carriers are used: 2 emergency service vehicles (responsible for 1.3% of the user coverage), 1 bus and 9 taxis (5.4% user coverage) and 952 drones for the remaining 93.3% user coverage. The number of used vehicles is quite limited compared to the ones available (Table 3). The reason is twofold. On the one hand, vehicles might not be located at a stop when the emergency occured as mentioned above (Section 2.1). On the other hand, the vehicles (and especially those of the public transportation) are gathered around stations (Table 3). Due to this, their geometrical coverage is quite limited. Furthermore, although a high amount of drones (i.e., 952) is used, they provision only 153 locations as multiple drones are needed per location in order to cover the 4h of needed intervention and the drone's fly time is limited (around 15 to 20 minutes including fly time to and from the location). For the considered scenario, on average 6 to 7 drones are needed to cover one location during the intervention.

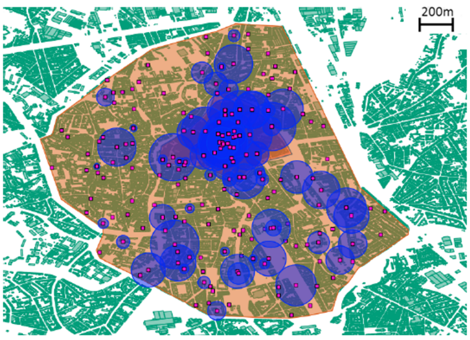

Figure 5: The used base station locations (red squares) and their coverage (blue circles).

Besides the carriers and base stations mentioned above to cover the residential users, 12 emergency service vehicles, 16 buses, and 101 taxis are additionally needed to cover 2% (i.e., 837) festival users. Approximately 98% of the festival users are out of range of the base stations installed in emergency service and public transport vehicles or the capacity of these femtocell base stations is completely used. In order to reconnect the other 98% festival users, drones will be needed. More precisely, 2252 extra drones have to be set in to provision 362 extra locations.

To summarize, if it is required to reconnect all of the residential and festival users, 3345 base stations are needed. 4.2% will have a vehicle as carrier, while 95.8% of them will be carried by a drone. Using the public transport and emergency service vehicles can alleviate some of the pressure on the drones. For the considered case, 5% of the base station locations could be provisioned by vehicles. One limitation of these vehicles is that their locations can not be chosen in the way this can be done with drones which often results in them being out of reach of all users.

4 Conclusion

Today's wireless access networks are very reliable but in case of an emergency, they can quickly become satured. One way to provide a temporary solution is to mount femtocell base stations on drones. One of the drawbacks of this solution is the high amount of drones needed when a large area such as a city center has to be covered. In this study, we investigate the potential of using femtocell base stations installed in emergency service and public transport (bus and taxi) vehicles to spread the traffic load in emergency ad-hoc network deployed by drone mounted base stations. To this end, a deployment tool for drone based networks is proposed which also accounts for the coverage already provided by the base stations installed in the public transport and emergency services vehicles. The tool has been applied on a realistic disaster scenario in the city center of Ghent, Belgium.

Our results show that it is possible to reduce the traffic handled by the drone mounted base stations, but the effect is rather limited. Only 5% of all the users in the affected area can be reconnected through the vehicles. The main reason is that the vehicle's location is known beforehand and can not be chosen freely as it is the case when using a drone as carrier. In order to cover all the users, 3204 drones will be needed. This high number of drones is due to the fact that we need on average 6 to 7 drones to cover a location throughout the complete 4h intervention as the fly time of a drone is limited. Our results clearly show that future research is needed to fully discover the potential of this type of solutions by including other types of drones (and carriers), serving users when the base station is 'on the move', different bit rate requirements (e.g., only sending text messages will be supported), cost calculations, and also the connection with the back haul network, which was beyond the scope of this study.

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5 References

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