HEINZ NIXDORF INSTITUT
UNIVERSITÄT PADERBORN

Philip Frerk

Wireless Protection of Vulnerable Road Users

Seminar Thesis in Master's Computer Science

4. Januar 2018

Please cite as:
Philip Frerk, "Wireless Protection of Vulnerable Road Users," Seminar Thesis (Seminararbeit), Heinz Nixdorf Institute, Paderborn University, Germany, January 2018.

Distributed Embedded Systems (CCS Labs)
Heinz Nixdorf Institute, Paderborn University, Germany

Fürstenallee 11 · 33102 Paderborn · Germany

http://www.ccs-labs.org/

Wireless Protection of Vulnerable Road Users

Seminar Thesis in Master's Computer Science

submitted by

Philip Frerk

born on March 31, 1994
in Bielefeld

created in the Working Group

Distributed Embedded Systems
(CCS Labs)

Heinz Nixdorf Institut
Universität Paderborn

Supervisor:	**Christoph Sommer**
Reviewers:	**Christoph Sommer**
	Falko Dressler
Submission date:	**4. Januar 2018**

Erklärung

Ich versichere, dass ich die Arbeit ohne fremde Hilfe und ohne Benutzung anderer als der angegebenen Quellen angefertigt habe und dass die Arbeit in gleicher oder ähnlicher Form noch keiner anderen Prüfungsbehörde vorgelegen hat und von dieser als Teil einer Prüfungsleistung angenommen wurde.
Alle Ausführungen, die wörtlich oder sinngemäß übernommen wurden, sind als solche gekennzeichnet.

Declaration

I declare that the work is entirely my own and was produced with no assistance from third parties.
I certify that the work has not been submitted in the same or any similar form for assessment to any other examining body and all references, direct and indirect, are indicated as such and have been cited accordingly.

(Philip Frerk)
Paderborn, 4. Januar 2018

Abstract

about 1/2 page:

1. Motivation (Why do we care?)
2. Problem statement (What problem are we trying to solve?)
3. Approach (How did we go about it)
4. Results (What's the answer?)
5. Conclusion (What are the implications of the answer?)

Protecting Vulnerable Road Users (VUs) is a very important task as in roughly 50 % of all traffic accidents VUs are involved. VUs are pedestrians or drivers of two-wheeled vehicles.

A technology is needed that warns both the VU and the car driver if an accident between them is likely to happen. This is a challenging task, because the warnings have to be sent in time and also it has to ensured that no people are warned who are not really affected by the approaching car.

To achieve that goal, wireless networks, GPS and sensor perception will be used.

Results show that the number of accidents with VUs involved can be reduced dramatically.

Therefore, much more work will be put into this topic, because it is already shown that the technologies can potentially prevent many traffic accidents.

Kurzfassung

Der Schutz gefährdeter Verkehrsteilnehmer ist eine sehr wichtige Aufgabe, denn in etwa 50 % aller Verkehrsunfälle sind gefährdete Verkehrsteilnehmer involviert. Gefährdete Verkehrsteilnehmer sind Fußgänger oder Fahrer von zweirädrigen Fahrzeugen.

Es wird eine Technologie benötigt, die sowohl den gefährdeten Verkehrsteilnehmer als auch den Autofahrer warnt, wenn ein Unfall zwischen ihnen wahrscheinlich ist. Das ist keine leichte Herausforderung, denn die Warnungen müssen rechtzeitig verschickt werden und es muss auch sichergestellt werden, dass keine Personen gewarnt werden, die nicht wirklich vom herannahenden Auto betroffen sind.

Um dieses Ziel zu erreichen, werden drahtlose Netzwerke, GPS und Sensorik eingesetzt.

Die Ergebnisse zeigen, dass die Zahl der Unfälle mit gefährdeten Verkehrsteilnehmern drastisch gesenkt werden kann.

Deshalb wird viel mehr Arbeit in dieses Thema gesteckt, denn es zeigt sich bereits, dass die Technologien viele Verkehrsunfälle potenziell verhindern können.

Contents

The table of contents should fit on one page. When in doubt, adjust the `tocdepth` counter.

Chapter 1

Introduction

umstrukturieren, vielleicht doch keine sektionen!

1.1 Motivation

Within the last century the usage of motorized vehicles has grown rapidly. While this fact brings the great benefit of full mobility, it does not come without its downsides. One of them is the high number of traffic accidents. According to **v2pcomm** in roughly half of all traffic accidents, Vulnerable Road Users (VUs) are involved. Hence, there is huge potential to prevent injuries or even deaths of many people. This thesis will give you an overview of the current state of research in this area. While there are many approaches beyond the discipline of Wireless Networking (e.g. Computer Vision for pedestrian recognition), this thesis will focus mainly on how to prevent traffic accidents by using wireless network technology. However, the other areas will also be explained briefly since they often work hand in hand with Wireless Networking.

1.2 Structure of the Thesis

The thesis is structured as follows. First, in chapter 2 we will look at so called Vehicle to Pedestrian Communication Systems (V2PCSs) which use wireless networks in order for pedestrian and vehicles to communicate so that accidents between them can be prevented.

Second, in chapter 3 we will look at detecting VUs by using perception of cars. We will only shortly dive into this topic, because it is not directly connected to Wireless Networking. Nevertheless, it is necessary to know the basics in order to understand chapter 4.

There, a combination of V2PCSs and perception will be used to improve the protection of VUs.

Finally, in chapter 5 all the approaches will be summarized and also we will see what future tasks are still left in this area to make it usable in the real world.

Chapter 2

V2P Communication Systems

The basic idea behind V2PCSs is that a driving vehicle (most often a car) and a VU (most often a pedestrian) exchange messages over a wireless network in order tell each other their positions. By doing that, accidents between them can be prevented because both the car driver and the pedestrian can react to the received messages.

There are several approaches to implements such a system and they will be discovered in this chapter.

2.1 With special Device

First, we will look at such communication systems which use a special device for the VU in order to send his messages. In **v2pprotection** and **watchover** such systems have been proposed.

The device from **v2pprotection** can be seen in the bottom of figure 2.1. In the top of figure 2.1 you can see the warning unit that will be installed in the car.

Figure 2.1 – The Warning Unit for Cars and the Warning Device for Pedestrians from **v2pprotection**

The task of the device for the pedestrian is to periodically send “Hello”-Messages including the pedestrian’s position so that the warning unit in the car can receive those messages and detect a probably dangerous situation. Then the warning unit sets itself into a warning status (which can be seen in figure 2.1).

It is very important that the car driver does not get too many warning messages because otherwise he would loose sensibility for the warning. Therefore, a key issue is to ensure that only warning are created if the distance between car and pedestrian decreases gradually.

Figure 2.2 shows the ratio of meaningful warnings divided by the number of all warning which is roughly 50% because in this test scenario only one pedestrian is present. That ratio is not satisfying, but is only because of the low number of pedestrians.

In figure 2.3 you see the same statistics, but for a scenario with 10 pedestrians. Here the same ratio is almost 100%.

hier fehlt noch warum die ratios so sind

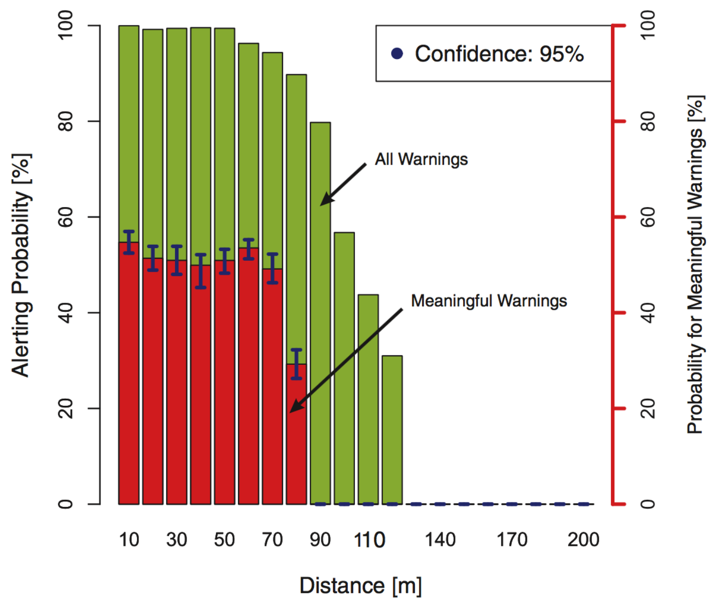


Figure 2.2 – Warning statistics in a test scenario with one pedestrian from **v2pprotection**

grafiken noch genauer erklären, vor allem mit der distanz

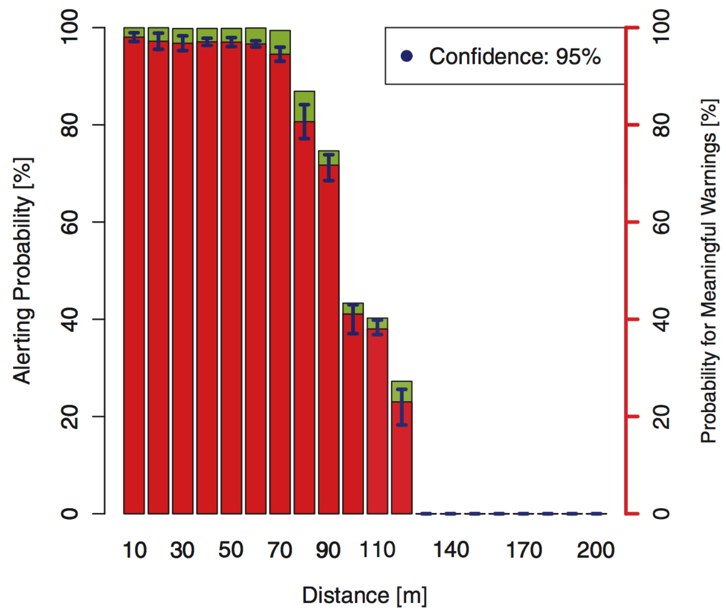


Figure 2.3 – Warning statistics in a test scenario with 10 pedestrians from **v2pprotection**

2.2 Using Smart Phones

In **v2pcomm** another approach has been developed which is based on the same idea as **v2pprotection** but it is more detailed. Moreover, it has the great benefit that no additional device for the VU is needed because in this system a smart phone or tablet will be used as the warning device for the pedestrians.

The approach is more detailed, because it formulates precise requirements that an implementation of a V2PCS should have in order to be able to work in reality. The requirements basically boil down to the following: One has to calculate the distance at which the warning messages are to be delivered. In section 2.1 we have already seen that this distance should not be too big, because otherwise too many meaningless warning would be received. But accordingly, the distance must not be too small, because the pedestrian and the car driver must have enough time to react to the messages.

To calculate this distance, the authors of **v2pcomm** have taken into consideration many parameters, e.g. the velocity of the car, the reaction time of the pedestrian, the expected positioning error of GPS (which is approximately 10m), the expected packet transmission time of Wi-Fi and so on. As an example, we take a look at equation 2.1 where the lower bound d_{min} of the distance is written down.

$$d_{min} = v \times (t_p + t_r + t_{tx}) + gnss_{err_{car}} + gnss_{err_{ped}} \tag{2.1}$$

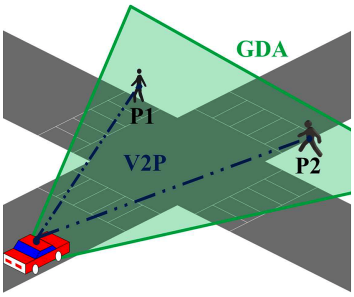
Here v is the car's velocity. Moreover, t_p is the time for perception of the pedestrian, t_r is the reaction time of the pedestrian, and t_{tx} is the packet transmission delay. $gnss_{err_{car}}$ and $gnss_{err_{ped}}$ are the positioning errors of the car and the pedestrian, respectively.

For simplification, we will not look in every detail of this calculation as it is very detailed. But in principle it is crucial to computer a lower and upper bound for the distance at which the warning messages should be sent. Because you can then check whether your system always fulfills these bounds which the system from **v2pcomm** does.

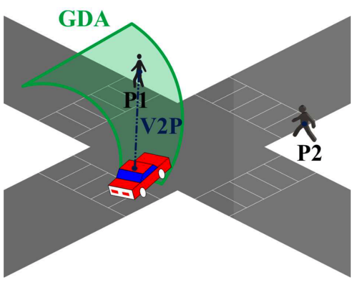
Finally, the distance calculated is 39.5, 52.3, and 72.0 m, when the velocity of the car is 30, 50, 80 km/h, respectively. **v2pcomm**

Another important concept in this context of when to send warning messages is the so called Geographical Destination Area (GDA). You can understand the concept by considering figure 2.4. In (a) a car is approaching to pedestrians, P1 and P2. As the car is yet far away from P1 and P2 it is possible that both P1 and P2 could be involved in an accidents with the car, therefore both of them are in the GDA.

In (b) the car has already come nearer to P1 and P2 and is currently turning left. Due to that fact, it is no longer possible for the car to approach the position of P2. So, P2 is no longer in the GDA of the car and P2 will not receive a warning message because of the car, only P2 will get one.



(a) Vehicle is moving straight.



(b) Vehicle is turning.

Figure 2.4 – The Geographical Destination Area of a moving car at two different points in time, from **v2pcomm**

The GDA of a car will be computed periodically and this makes sure that even less meaningless warning messages will be sent. The GDA can be computed by taking several parameters of the car (e.g. the yaw rate) into account.

jetzt erwähnen dass wlan auch lange dauert und so auf nächste sektion hinleiten

2.3 Faster WiFi Message Exchange by using Beacon Stuffing

The principle from chapter 2.2 has one disadvantage that has not yet been emphasized. Typically, when two devices want to communicate with each other over WiFi, they have to establish a WiFi connection first. This process takes time

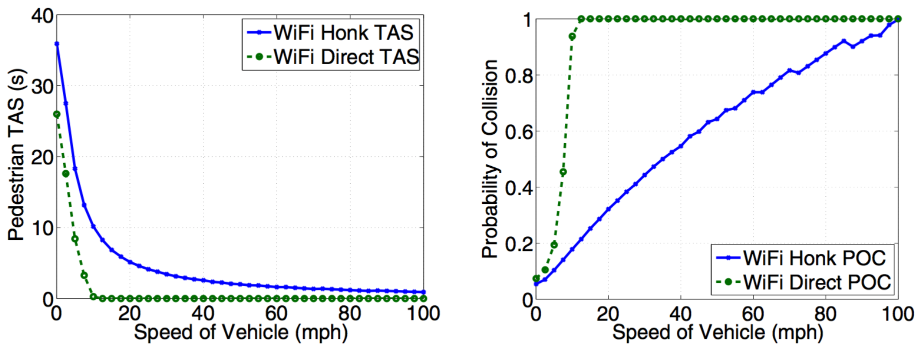
WIE VIEL ZEIT??

. But there is an approach from the authors of **beacon** to avoid that connection establishing phase by using WiFi Beacon Stuffing. Beacons are usually used in order to propagate the existence of a WiFi network. They are broadcasted periodically by the WiFi access point and contain information about the network (e.g. the SSID).

In **beacon** the SSID field is replaced by a so called WiFi Honk Information Packet, which includes information about the moving car, namely the latitude, longitude, speed, and direction. VUs or other cars then receive this information and compute the likelihood of an accident.

Figure 2.5 shows the results of **beacon** compared to WiFi without Beacon Stuffing. Sub figure (a) shows that pedestrians have a little more time to react, but obviously if the velocity of the car comes close to 100 mph there is almost no time to react. Sub figure (b) shows the probability of collision on which Beacon Stuffing has a decisive impact. Whereas the plot normal WiFi has an exponential growth, the growth of the plot for WiFi Honk (Beacon Stuffing) is only linear. Therefore, warning messages can be sent more aggressively.

WARUM???



(a) VRU time available to stop (b) Probability of collision

Figure 2.5 – Evaluation of Beacon Stuffing, from **beacon**
POC stands for "Probability of Collision", TAS stands for "Time available to stop".

Chapter 3

Detecting Pedestrians by using Perception

Hier kommt nur ein kleiner Ausblick hin, da es nicht direkt etwas mit Wireless Networking zu tun hat

Chapter 4

Fusion of Perception and V2P Communication

Chapter 5

Conclusion

- summarize again what your paper did, but now emphasize more the results, and comparisons
- write conclusions that can be drawn from the results found and the discussion presented in the paper
- future work (be very brief, explain what, but not much how, do not speculate about results or impact)
- recommended length: one page.

List of Abbreviations

GDA	Geographical Destination Area
V2PCS	Vehicle to Pedestrian Communication System
VU	Vulnerable Road User

List of Figures

Todo list