PV-Alert: Vulnerable Road User Alert System With An Advanced Map Matching Algorithm In A Fog-based Architecture

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Motivation

Statistics of road accidents

World Health Organization 2015:

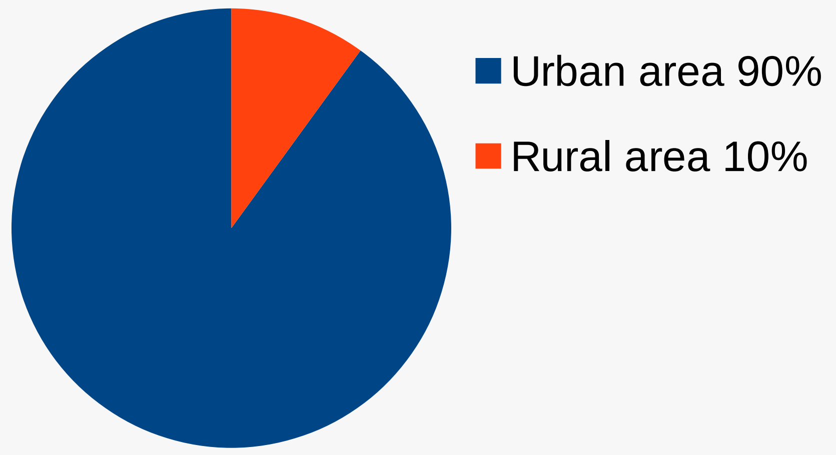
1.2 million

injuries each year.

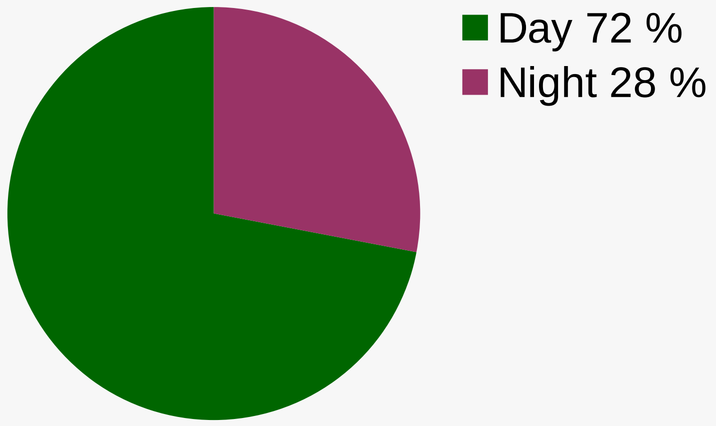
Category	2000	2010
Pedestrians	10.4 %	12.1 %
Cyclists	3.3 %	3.7 %
Cyclo-motoristes	5.6 %	6.2 %
Motorcyclists	11.6 %	17.6 %

Distribution of fatal road accidents according to different users categories

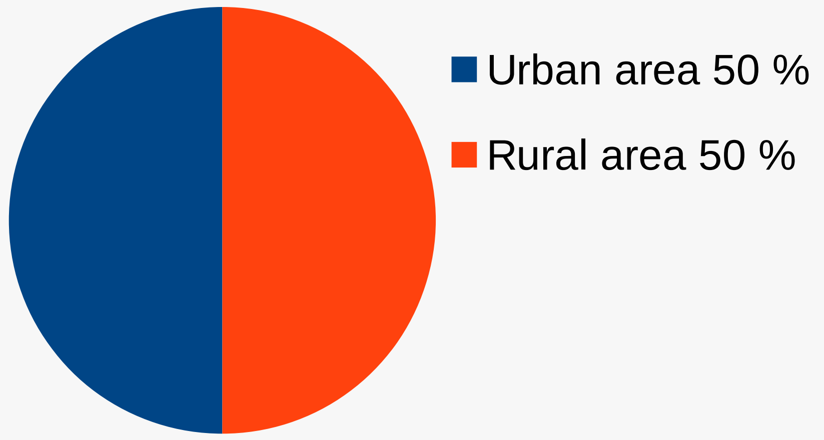
The French Road Safety Observatory (ONISR)



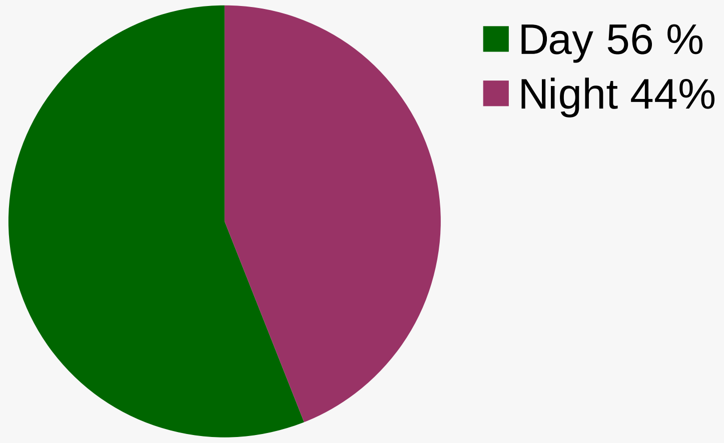
Accidents by external environment.



Accidents by time of day



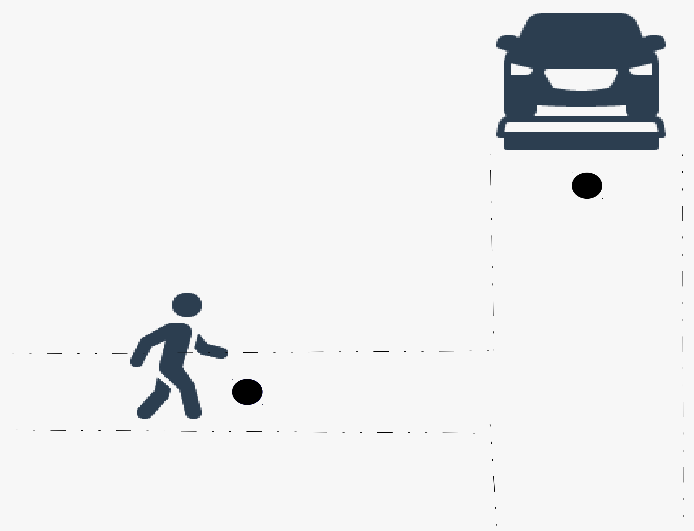
Fatal *accidents by external environment.*



Fatal *accidents by time of day*

State of art

3 projects, 3 deferent technologies



1) Systems based on radars

European projects: PROTECTOR and SAVE-U

Design a pedestrian protection systems based on multi-sensors: **Radars**, **Cameras** and **Laser sensors**

2) Systems based on visual or infrared sensors

French project: “Logiciels d’observation des usagers vulnérables”

Design a pedestrian perception systems based on: **Laser sensors**, **monovison** and **stereovision**

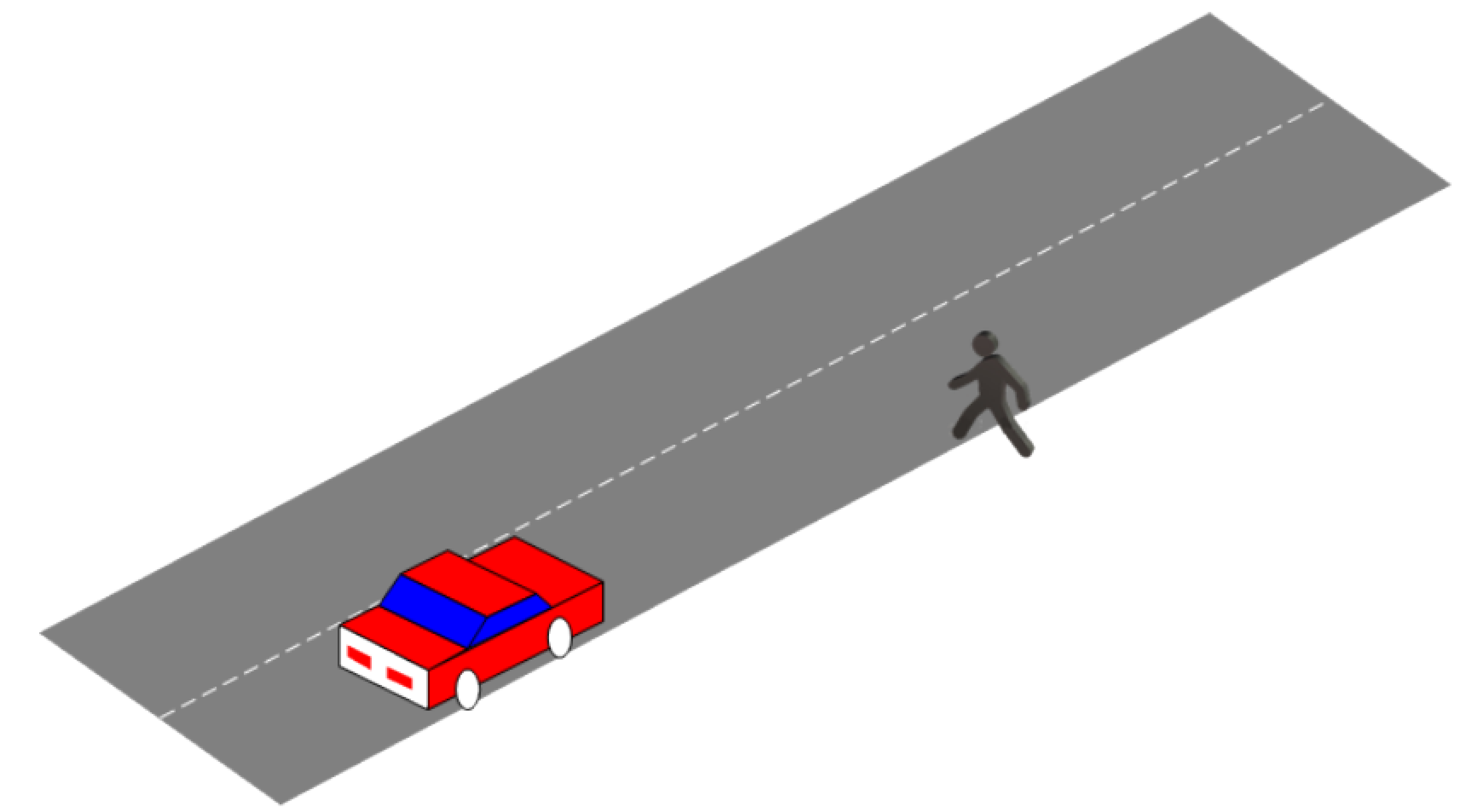
3) Systems based on intelligent road infrastructures

Project combining means of perception and communication: WATCH-OVER

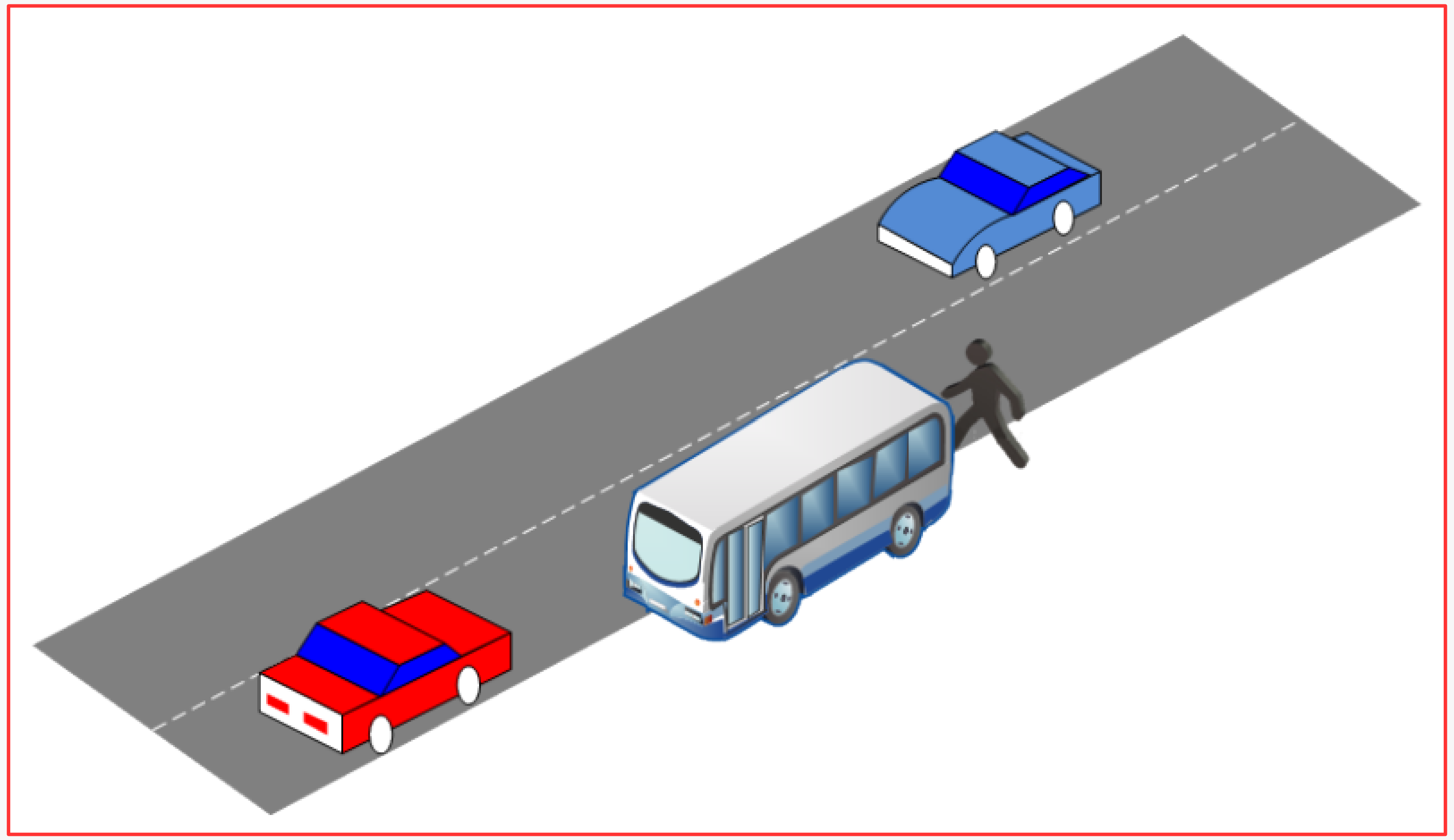
Vehicle-to-**V**ulnerable ro**A**d user coopera**T**ive communication and sensing te**CH**nologies to impr**O**ve transpo**R**t safety

Problematic

Perception problem



Pedestrian crossing street in front of vehicle

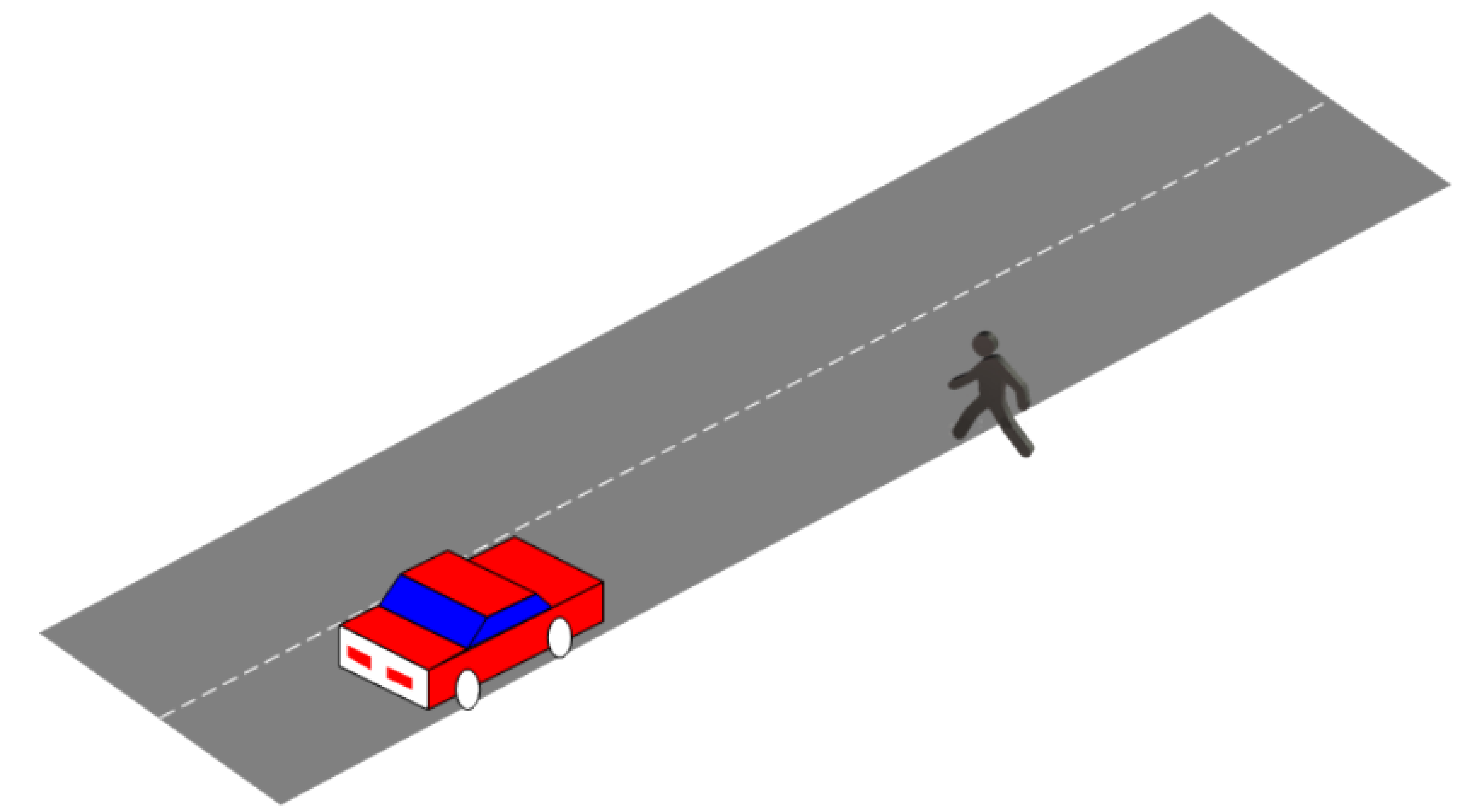


Pedestrian masked by an obstacle

*Problem: Lack of means of **perception** and **communication** for drivers and pedestrians*

Problematic

Perception problem



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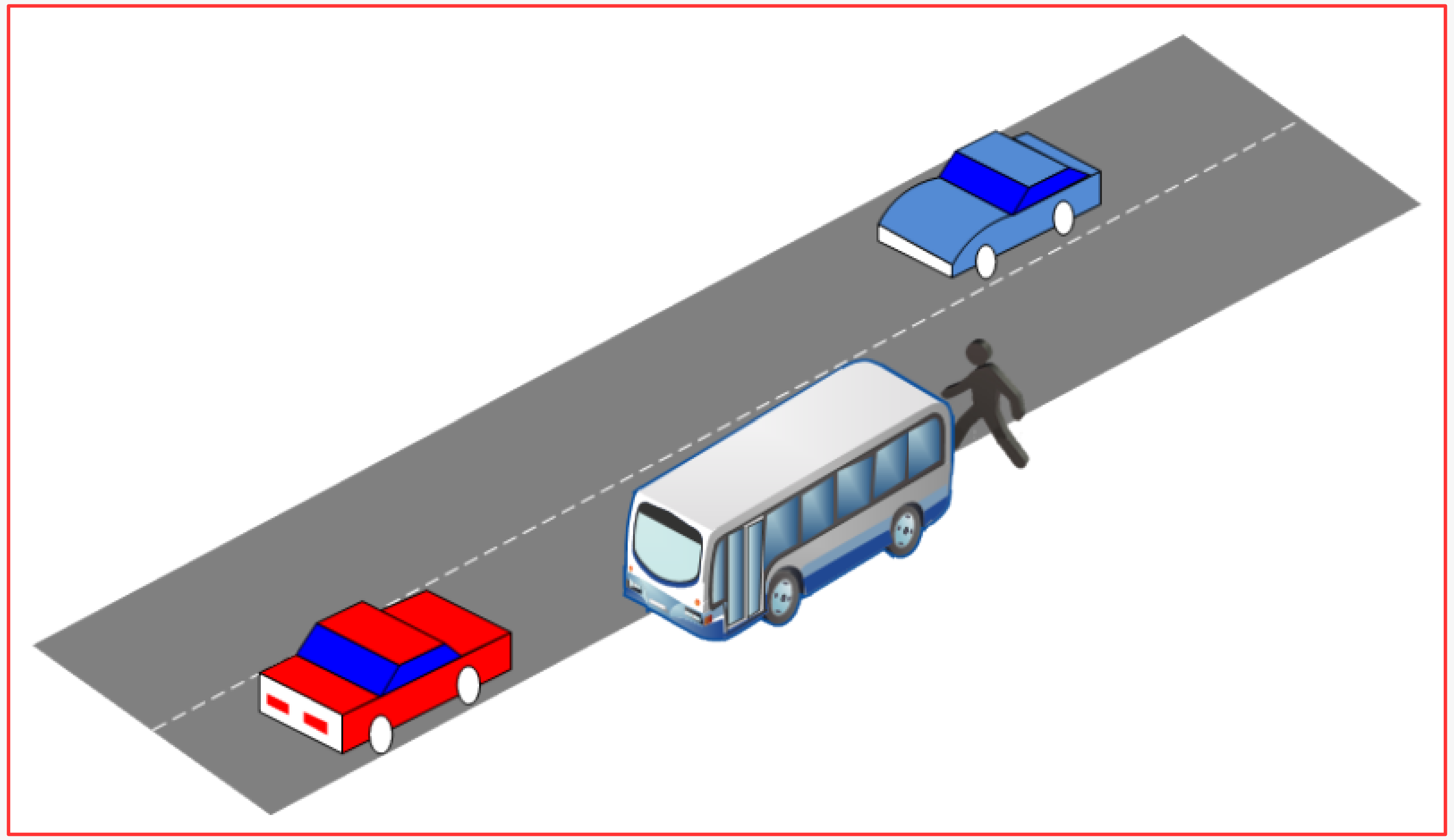
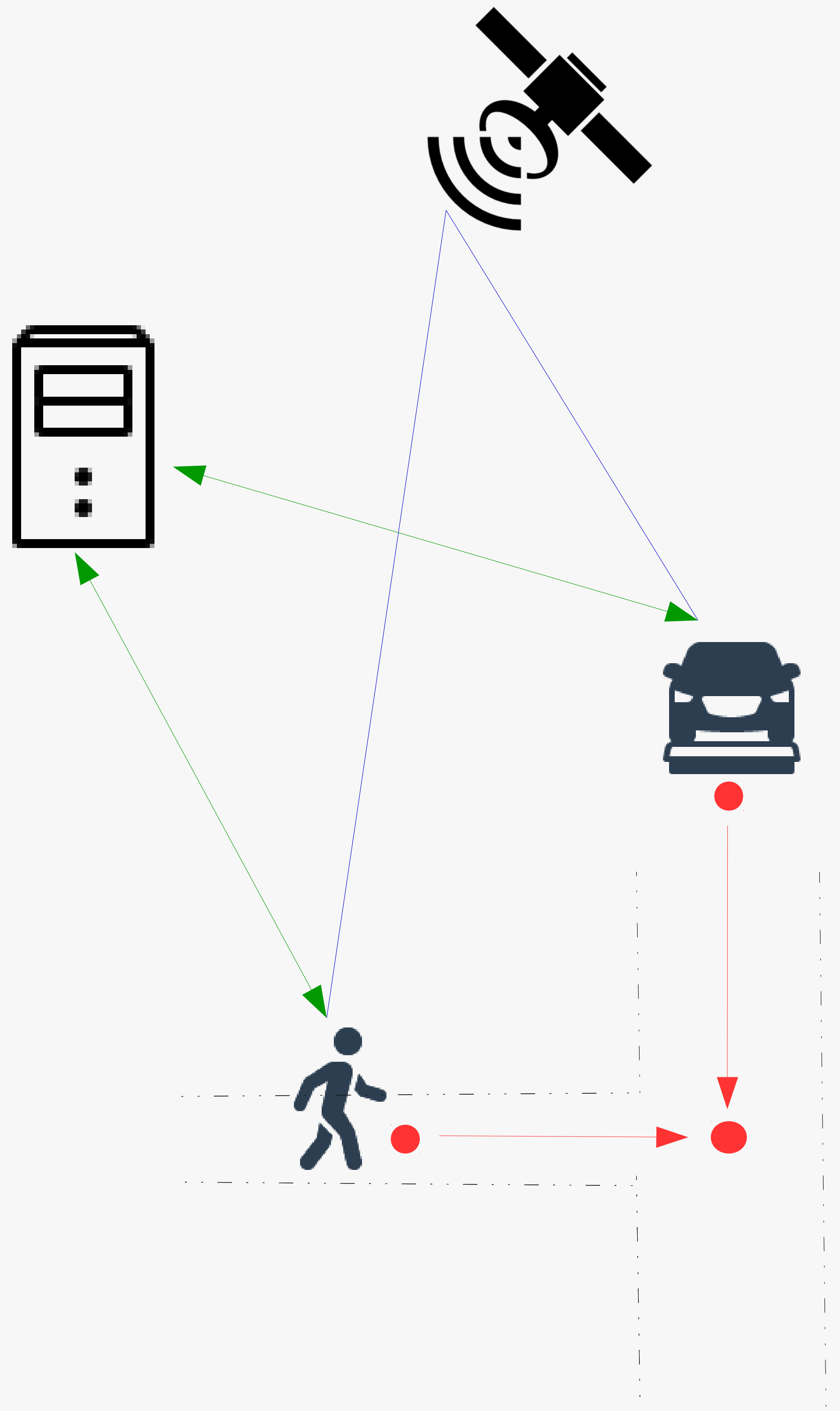


Pedestrian masked by an obstacle

*Problem: Lack of means of **perception** and **communication** for drivers and pedestrians*
*Solution: Use Smartphone with GPS localization for **perception** and **communication***

Challenges

Vulnerable road users alert system



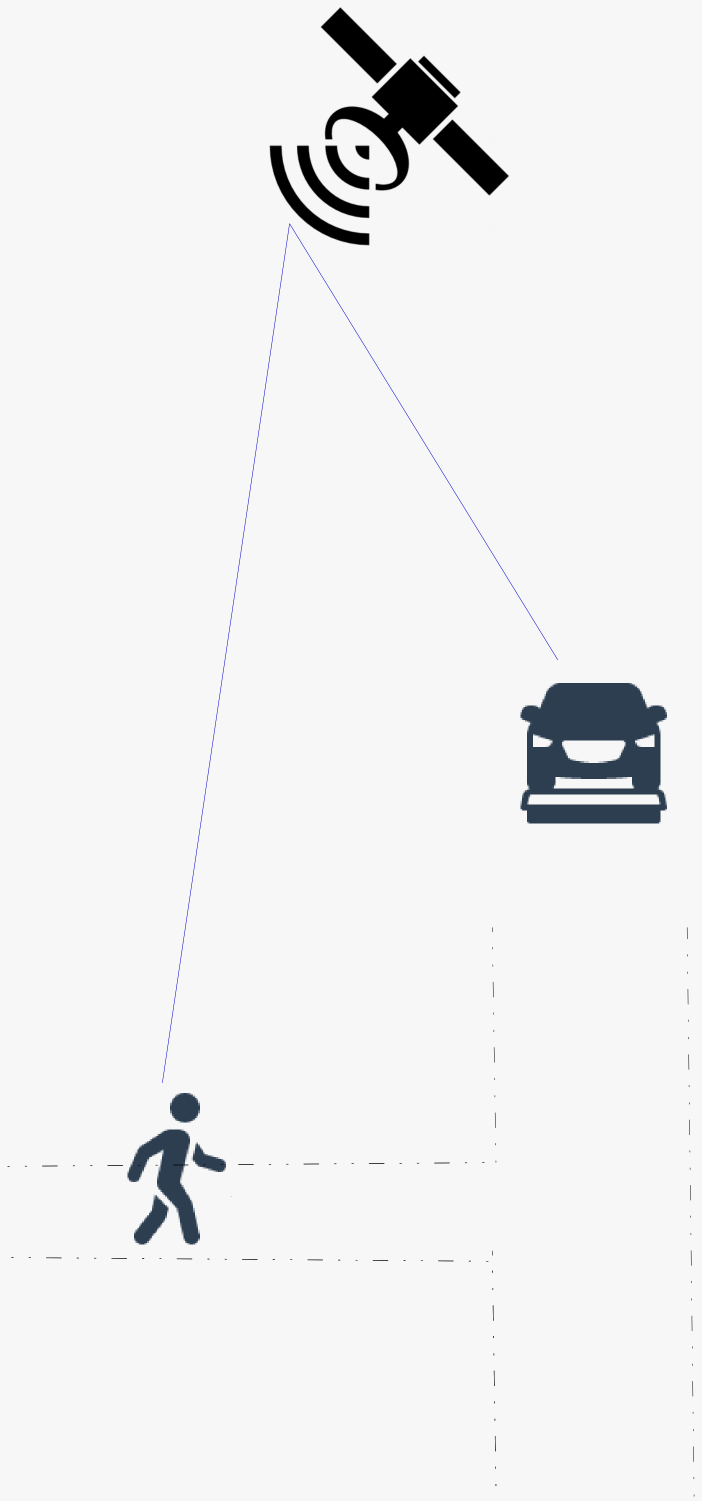
01 High GPS accuracy

02 Low latency communication

03 An efficient collision prediction algorithm

Challenges

Vulnerable road users alert system



An efficient collision prediction algorithm

03

Low latency communication

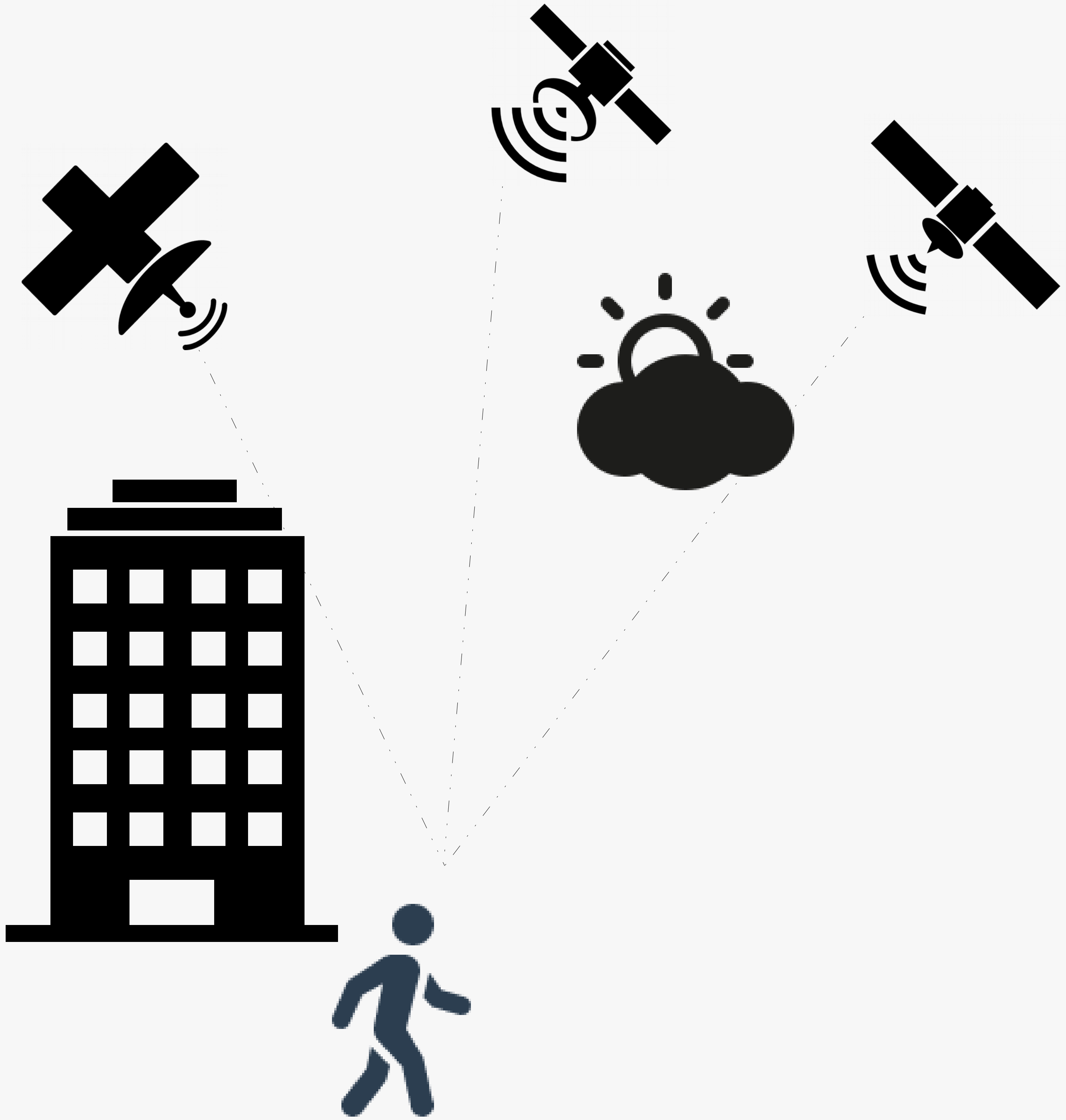
02

High GPS accuracy

01

GPS accuracy

Area and weather conditions



GPS accuracy depends on:

- Signal strength

- Weather conditions

- Building obstacle

- Noise and interference

How can we increase GPS accuracy ?

- Hardware-based approach:

- Eliminate noise and interference (signal processing)

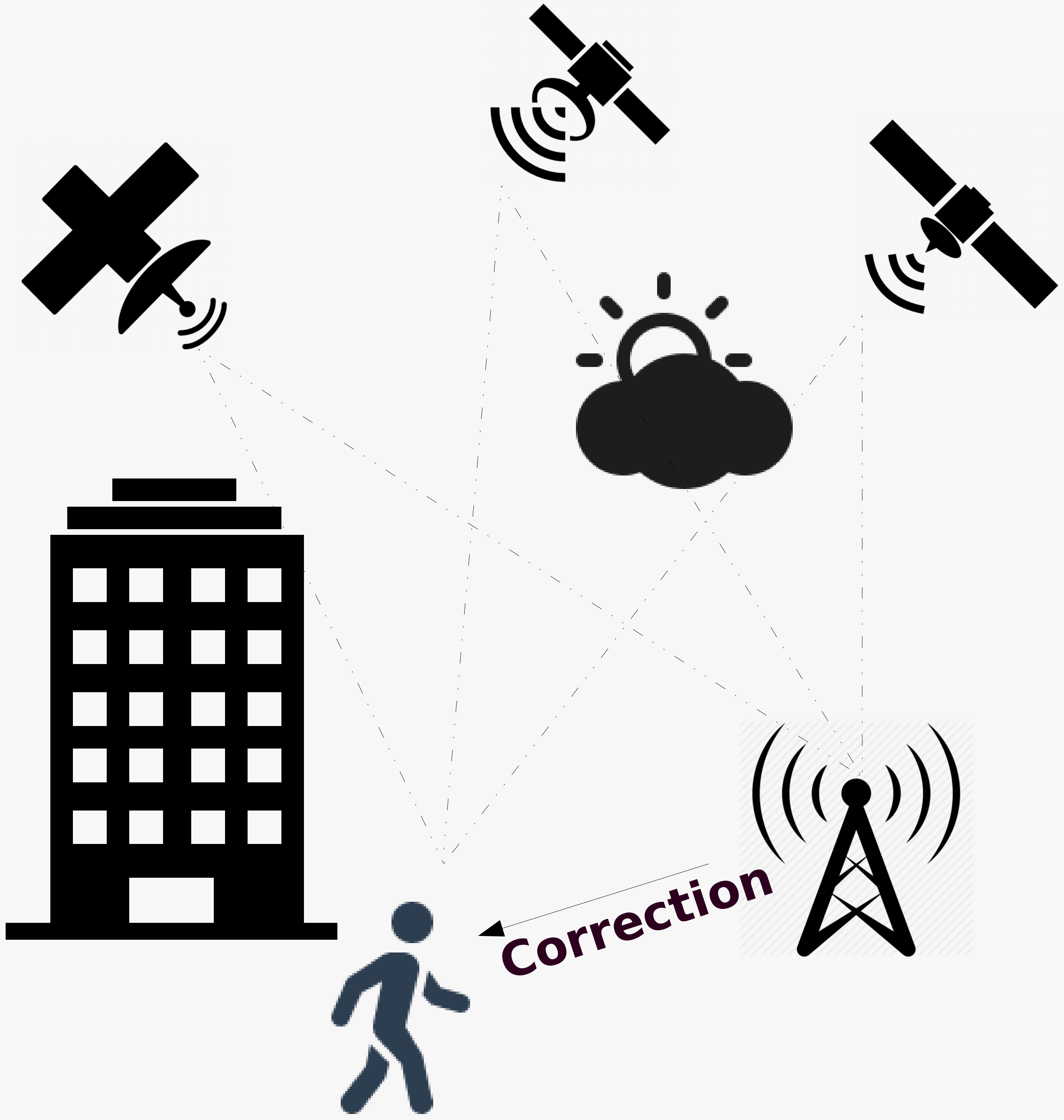
- Deferential GPS (Base station approach)

- Software-based approach:

- Use map information to correct the location

Hardware-based approach

Deferential GPS



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Software-based approach

Map-matching approach

GPS accuracy depends on:

- Signal strength

- Weather condition

- Building obstacle

- Noise and interference

How can we increase GPS accuracy ?

- Hardware-based approach:

- Eliminate noise and interference (signal processing)

- Deferential GPS (Base station approach)

- Software-based approach:

- Use map matching to correct GPS location

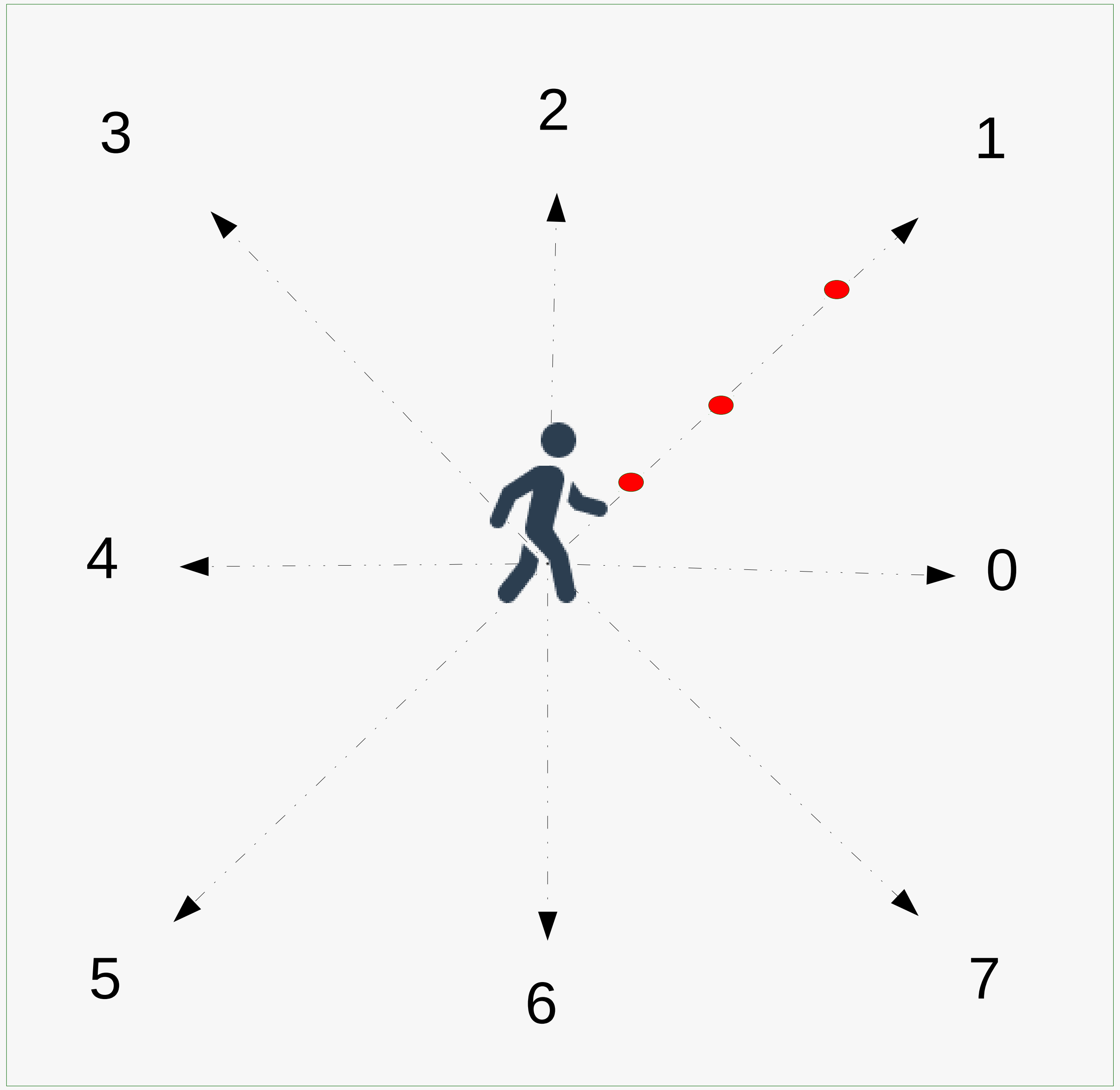
Idea

Increase horizontal accuracy

Pedestrians often take horizontal trajectory

Horizontal accuracy evaluation test

Experimental setup



D0	D1	D2	D3	D4	D5	D6	D7
0°	45°	90°	135°	180°	225°	270°	315°

d0	d1	d2	d3	d4	d5	d6	d7	d8
1m	3m	6m	9m	12m	15m	18m	21m	25m

Table 1: *Directions (D) and distances (d) of measurements*

4 scenarios

1) Rural area in a sunny day.

2) Rural area in a cloudy day

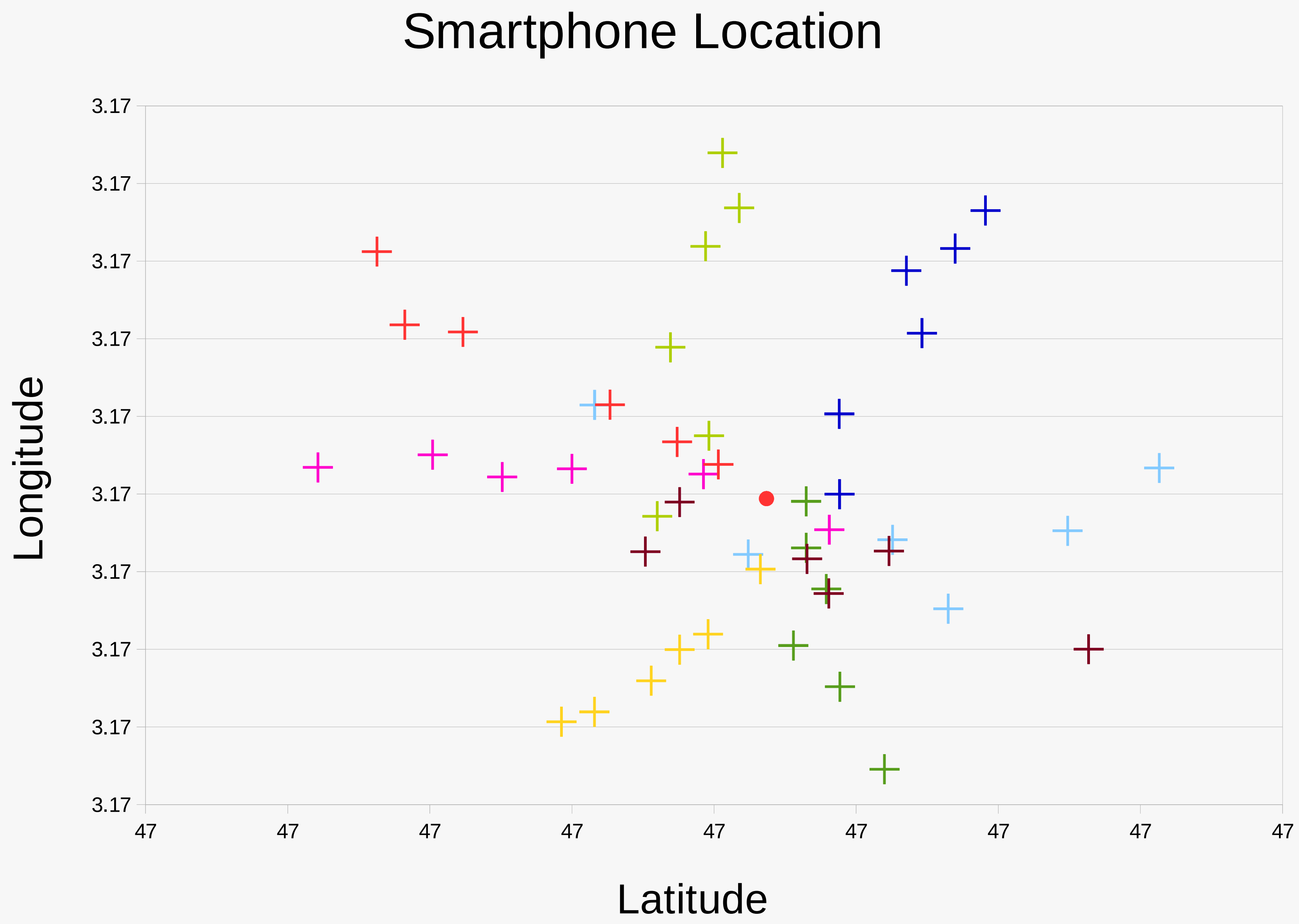
3) Urban area in a sunny day

4) Urban area in a cloudy day

Urban area

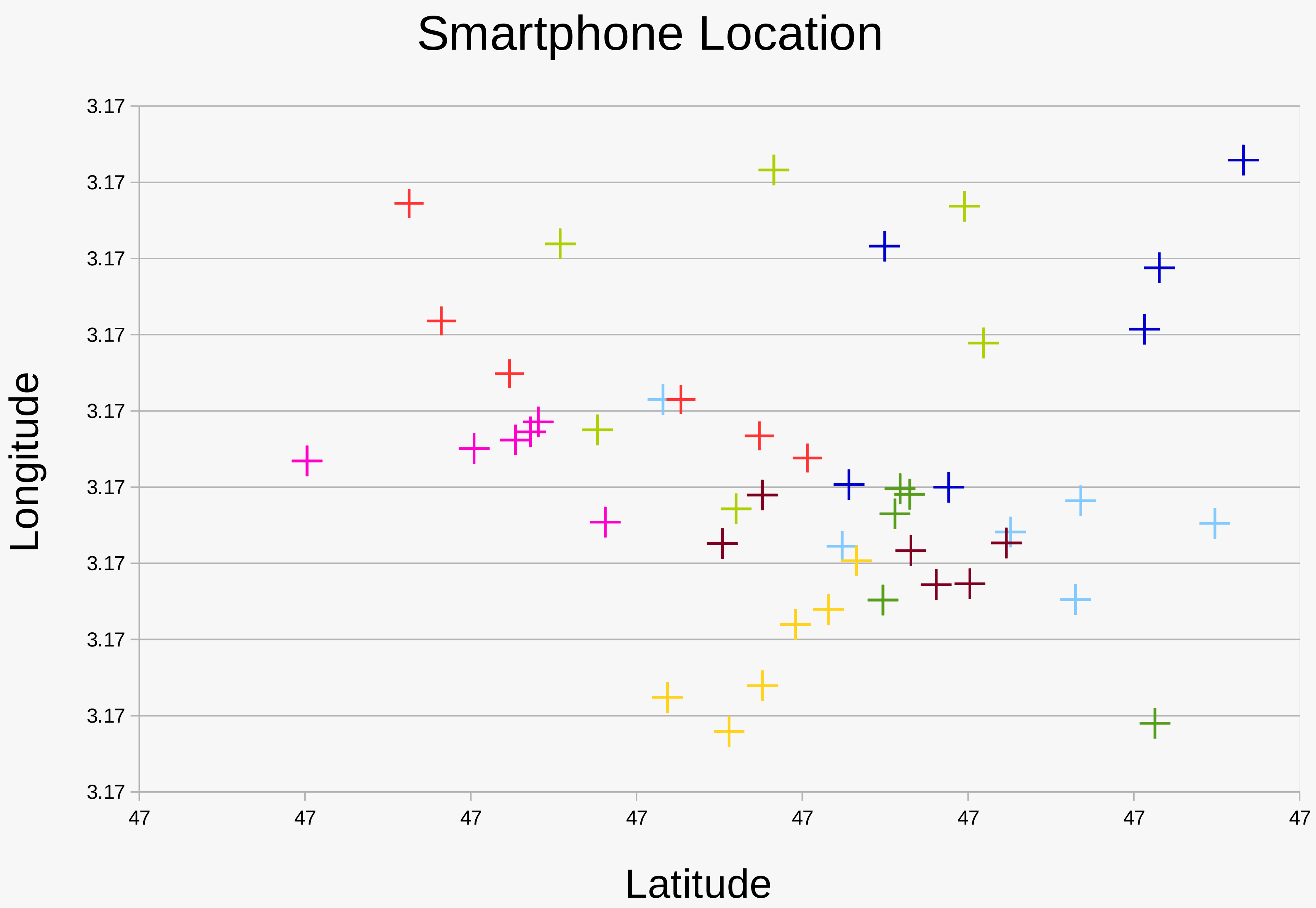
Horizontal accuracy evaluation

Sunny day



GPS error: 2 to 7 meters

Cloudy day

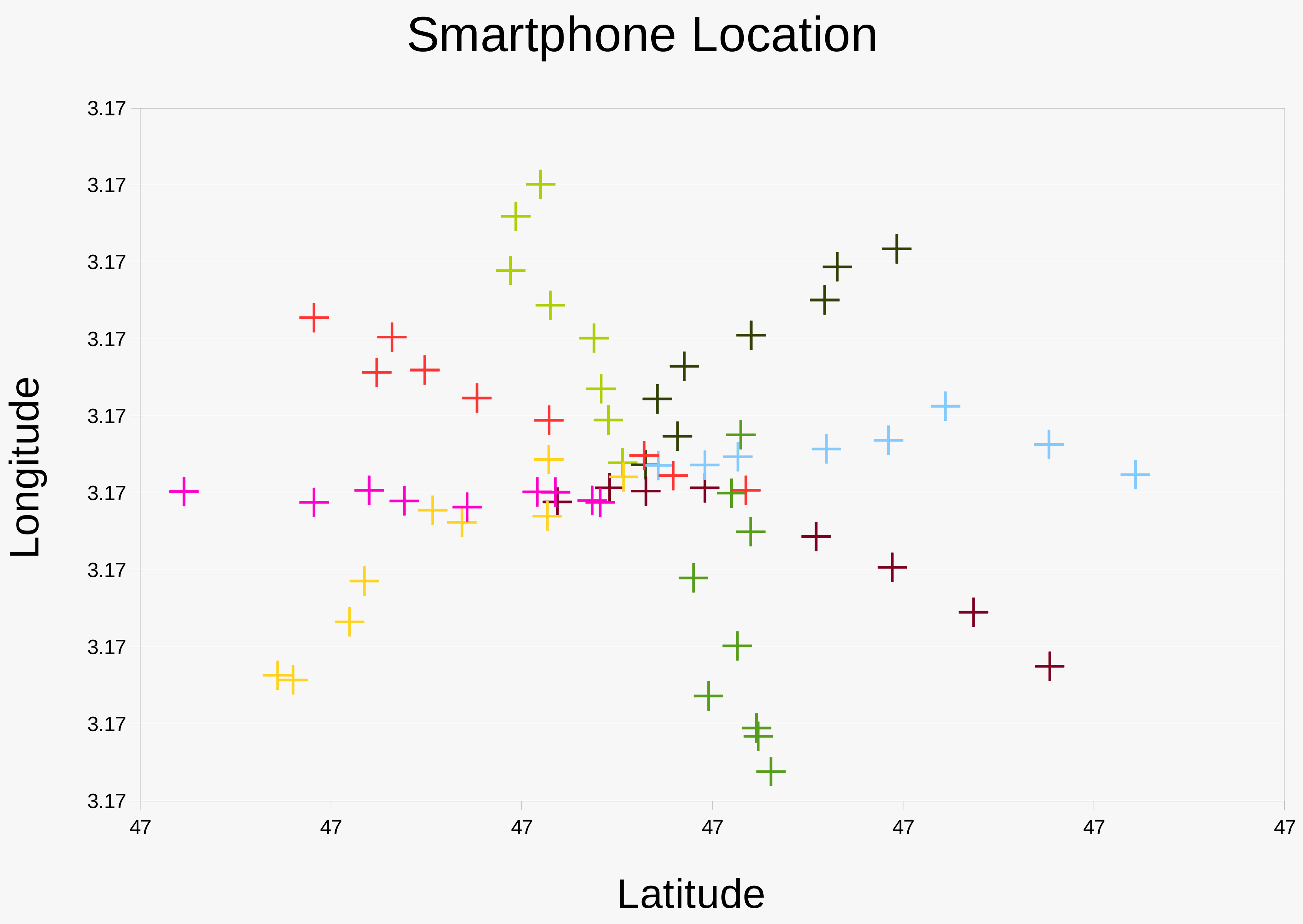


GPS error: 3 to 9 meters

Rural area

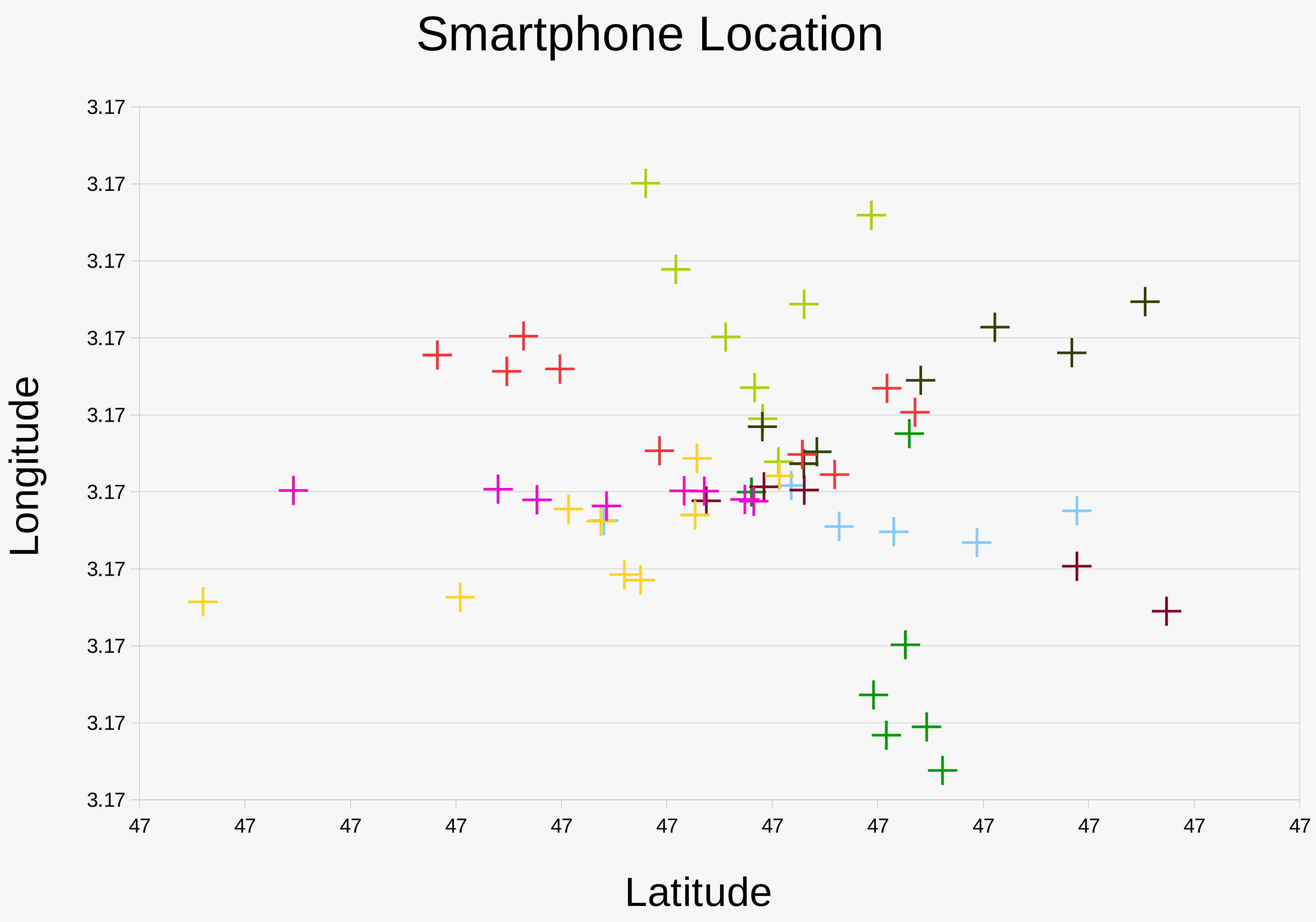
Horizontal accuracy evaluation

Sunny day



GPS error: 2 to 3 meters

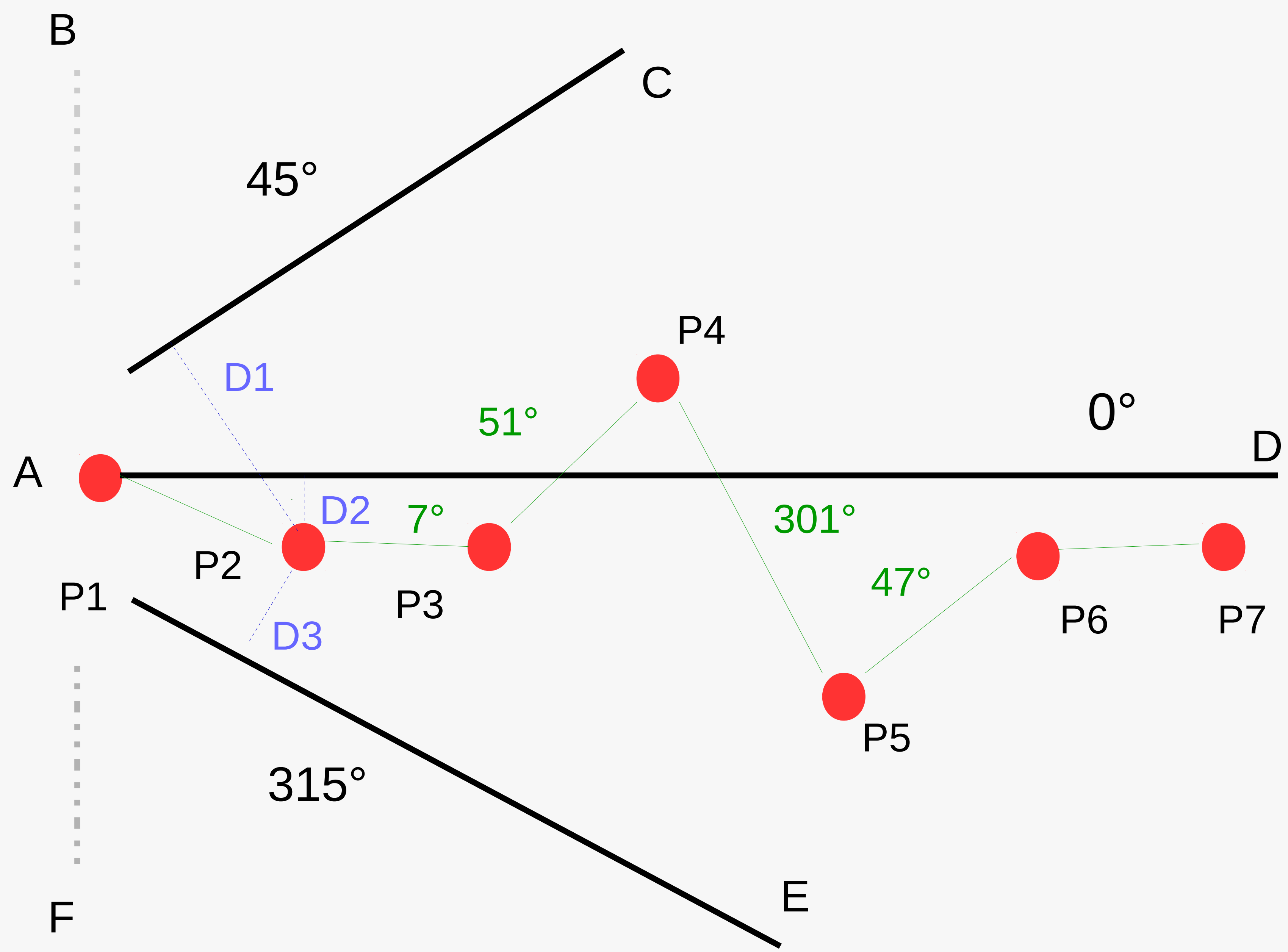
Cloudy day



GPS error: 2 to 6 meters

Map matching algorithm (Step1)

Chain-Code-based Map Matching Technique

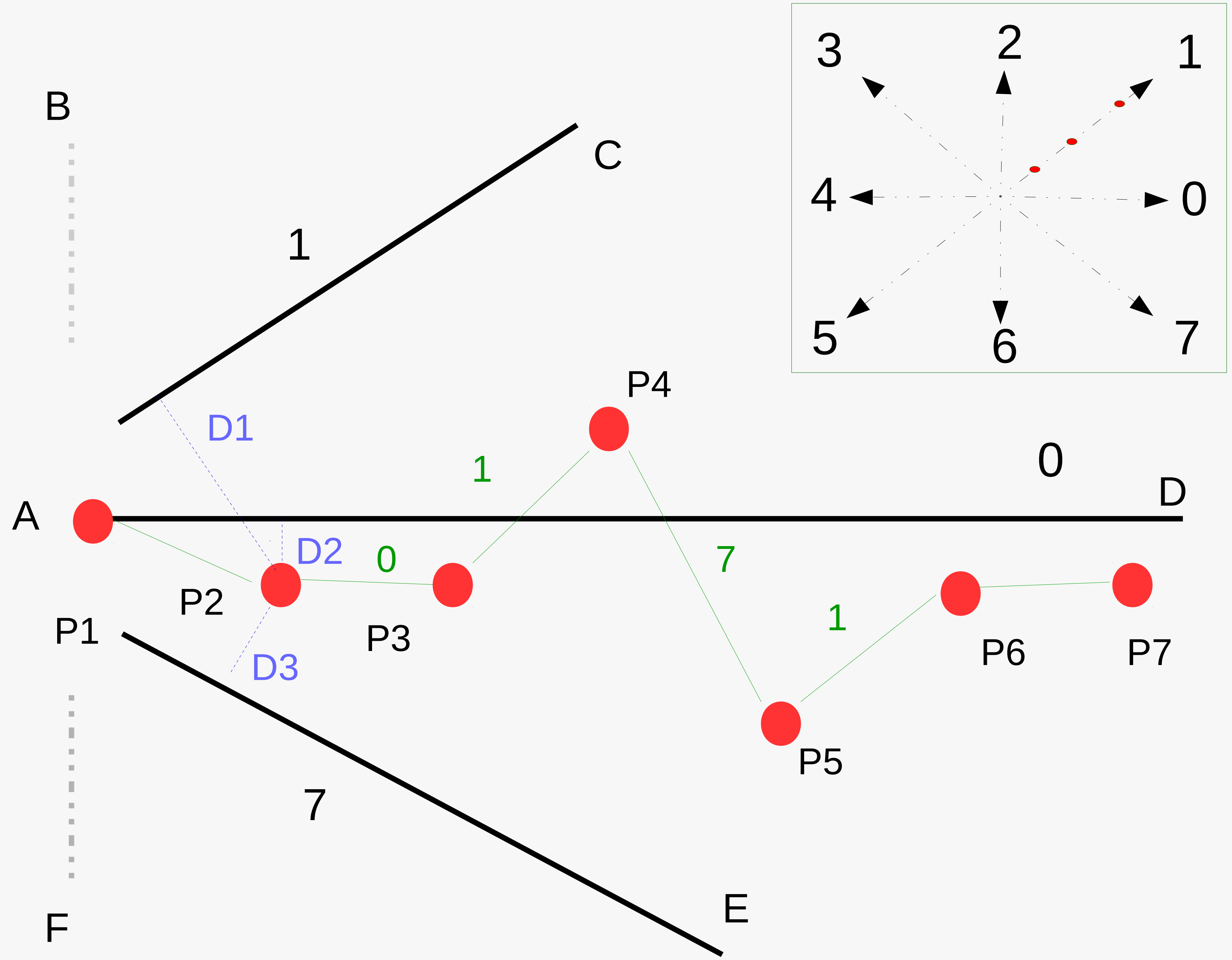


Δ = |(Pedestrian direction)° – (Segment direction)°|

Segment	Distance	Δ1	Δ2	Δ3	Δ4
AC	D1	38°	6°	256°	2°
AD	D2	7°	51°	301°	47°
AE	D3	308°	264°	14°	268°

Map matching algorithm (Step2)

Chain-Code-based Map Matching Technique

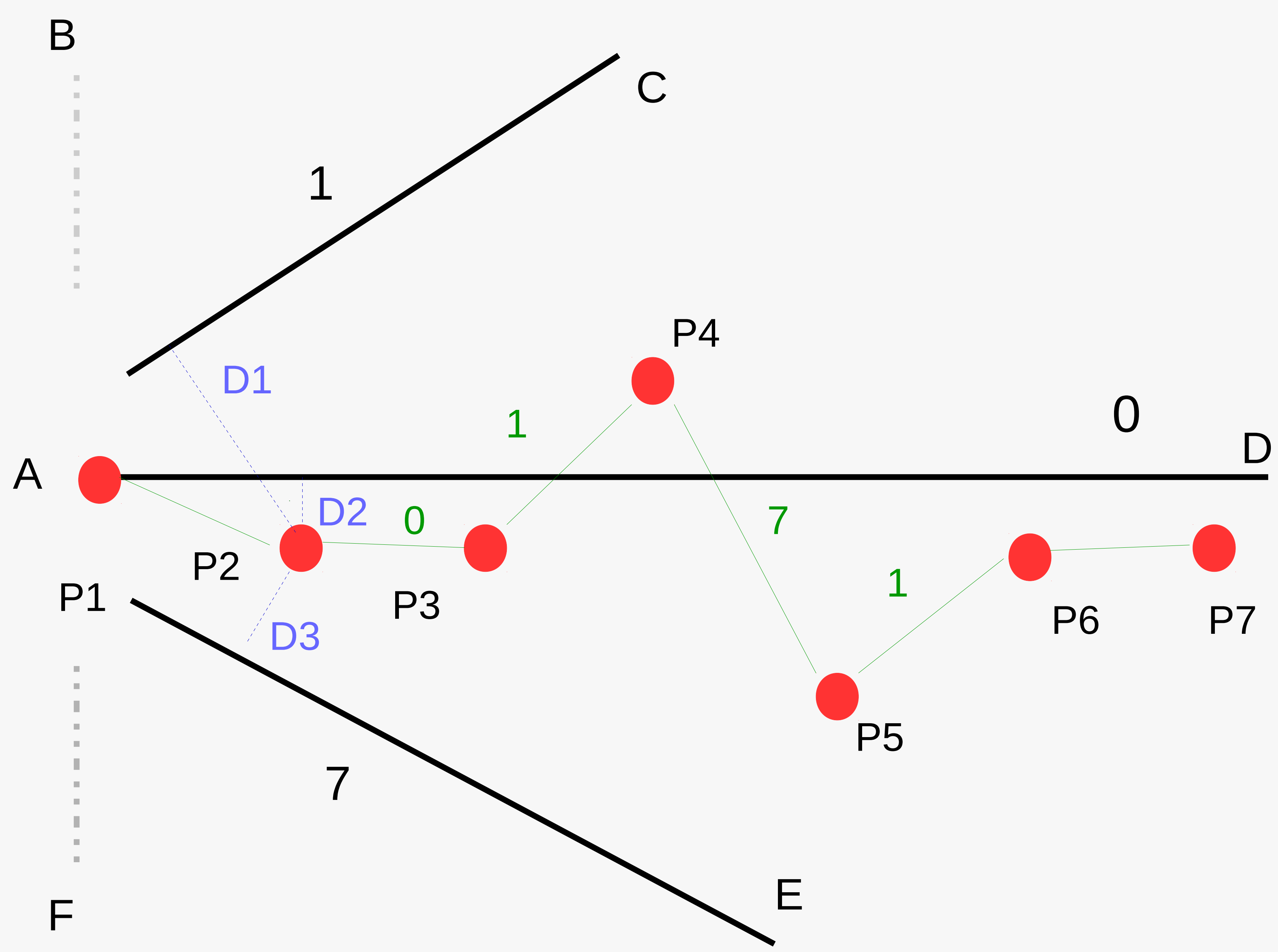


Δ = |Chain-Code [Pedestrian] – Chain-Code [Segment]|

Segment	Distance	Δ1	Δ2	Δ3	Δ4
AC	D1	1	0	6	0
AD	D2	0	1	7	1
AE	D3	7	6	0	6

Map matching algorithm (Step3)

Chain-Code-based Map Matching Technique



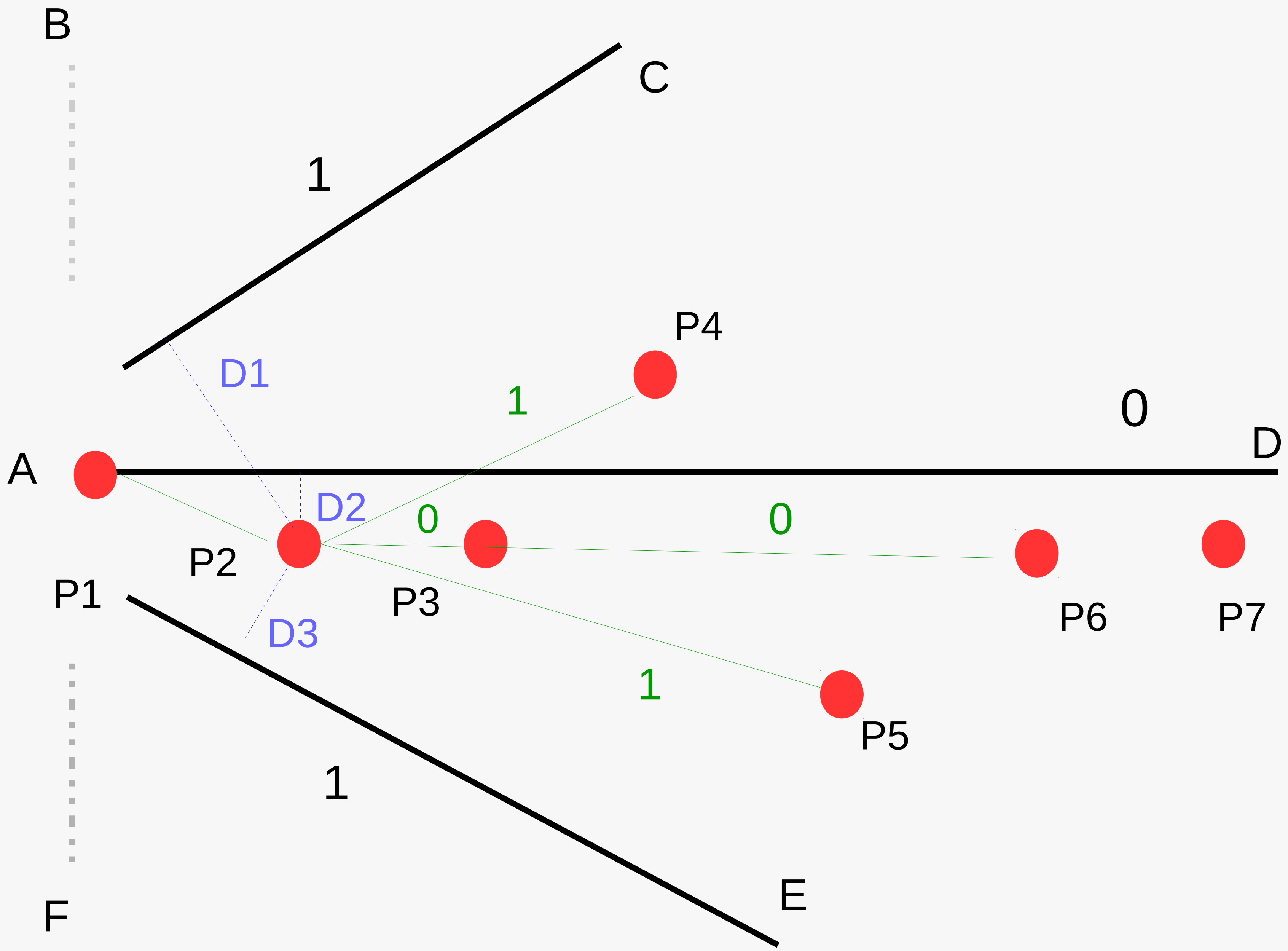
$\Delta = |$Chain-Code [Pedestrian] – Chain-Code [Segment]$|$

$$\mathrm{Dcc} = \begin{cases} \Delta & \Delta < 4 \\ (|\Delta - 8|) \bmod 4 & \text{otherwise} \end{cases}$$

Segment	Distance	DCC1	DCC2	DCC3	DCC4
AC	D1	1	0	2	0
AD	D2	0	1	1	1
AE	D3	1	2	0	2

Map matching algorithm (Step4)

Chain-Code-based Map Matching Technique

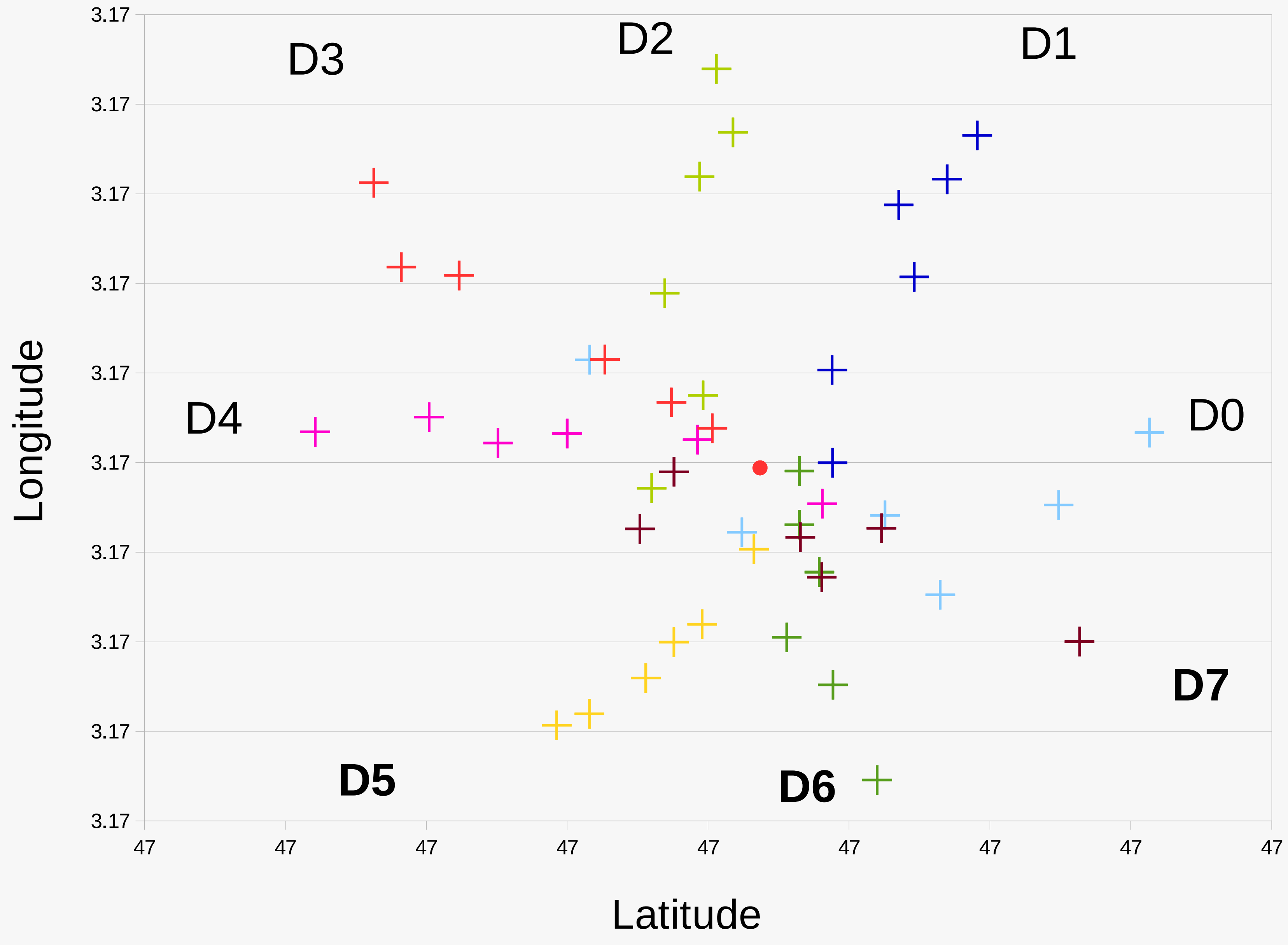


$\Delta = |\text{Chain-Code [Pedestrian]} - \text{Chain-Code [Segment]}|$

$$Dcc = \begin{cases} \Delta & \Delta < 4 \\ (|\Delta - 8|) \bmod 4 & \text{otherwise} \end{cases}$$

Segment	Distance	DCC1	DCC2	DCC3	DCC4
AC	D1	1	0	2	1
AD	D2	0	1	1	0
AE	D3	1	2	0	1

Map matching algorithm



2 Models:

- *Linear model*
- *Non-linear model:*
  - *Radial basis functional neural network*

4 Scenarios:

- *2 different areas:*
  - *Urban and Rural area*
- *2 different weather conditions*
  - *Sunny and cloudy day*

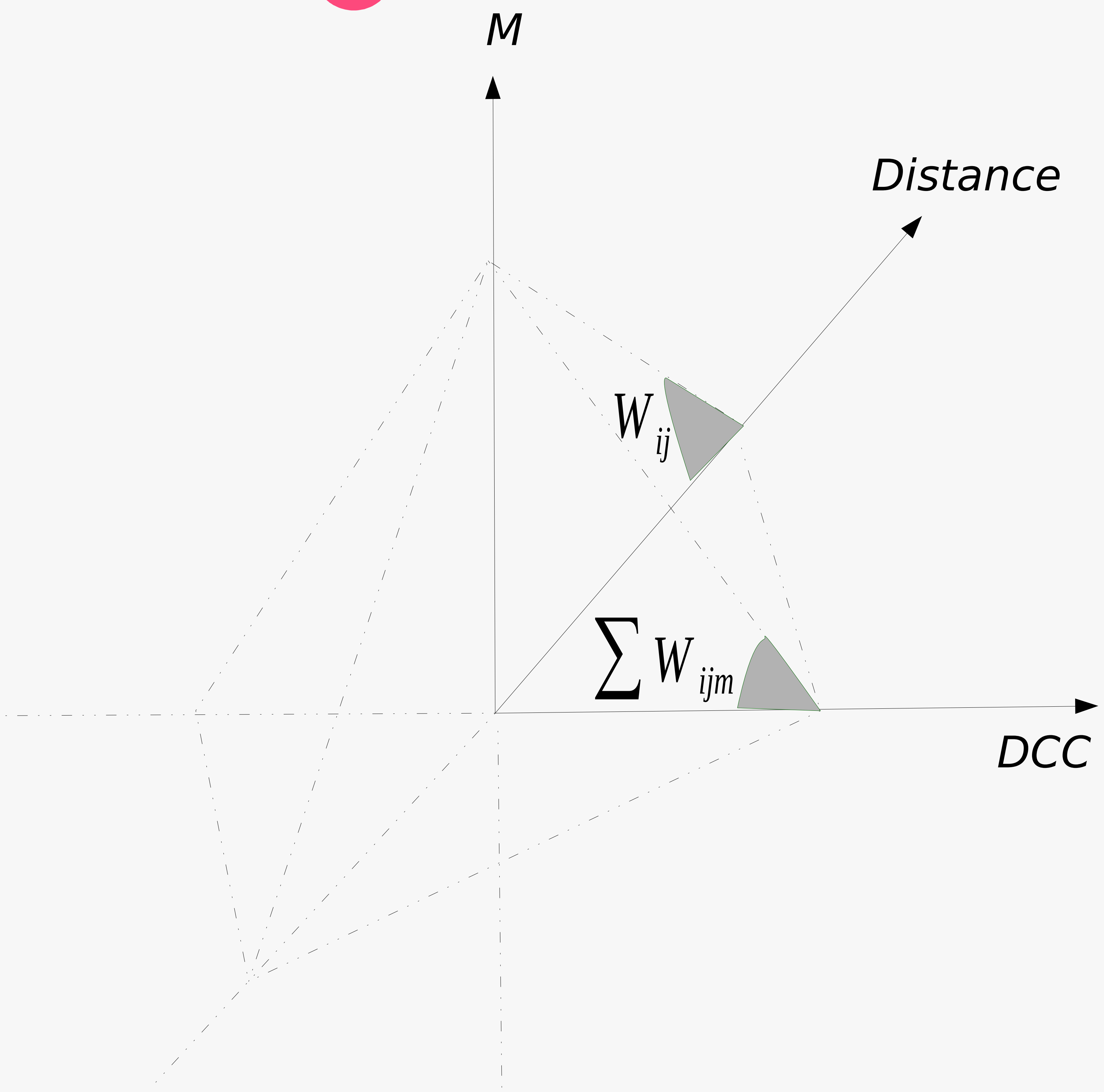
Training data:

- *5 directions (D0-D4)*

Testing data:

- *3 directions (D5-D7)*

Linear model



Segment	Distance	DCC1	DCC2	DCC3	DCC4
AC	D1	1	0	2	1
AD	D2	0	1	1	0
AE	D3	1	2	0	1

$$V_{ij}=W_{ij}*D_{ij}+\sum_{m=1}^{4} W_{ijm}*Dcc(Step[i+m],Segment[j])$$

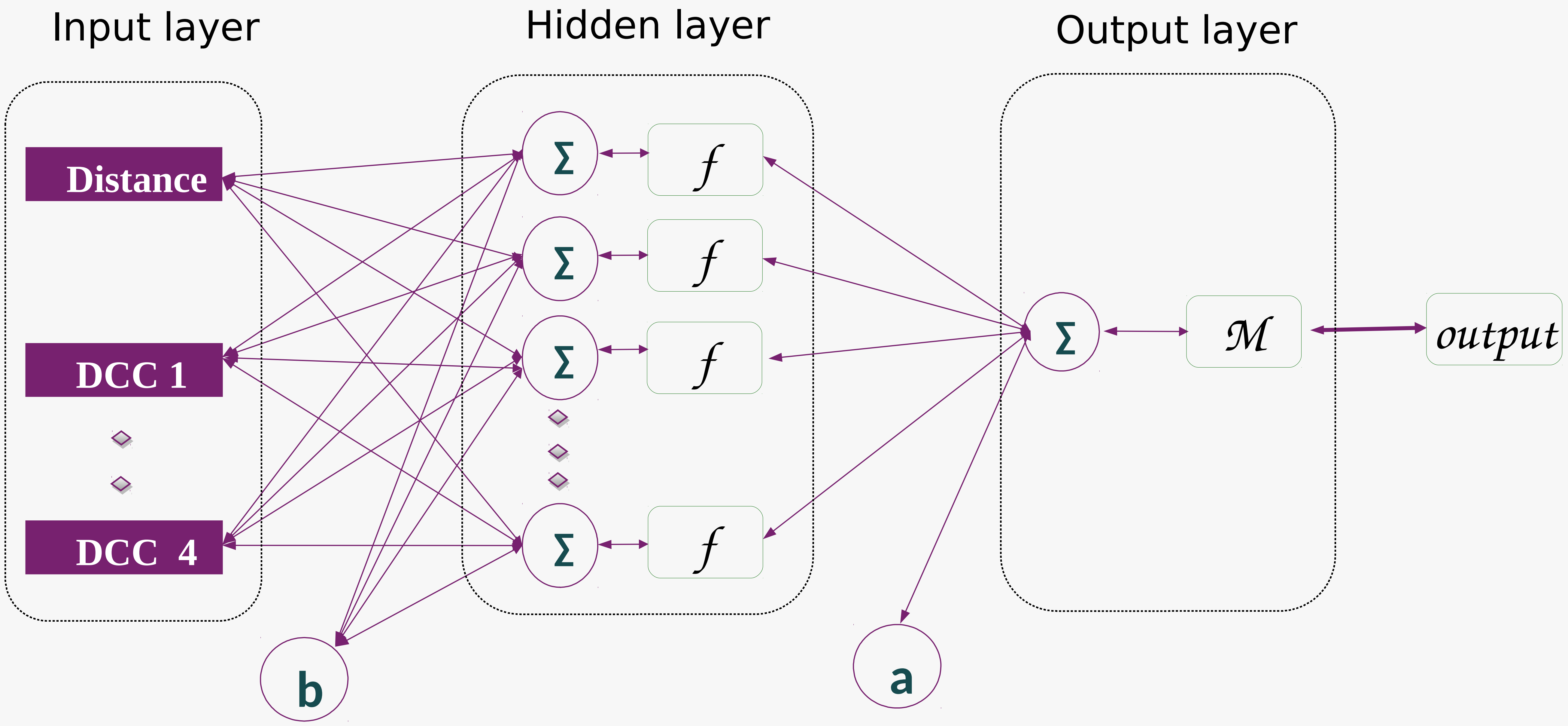
$$M_{ij}=1/V_{ij}$$

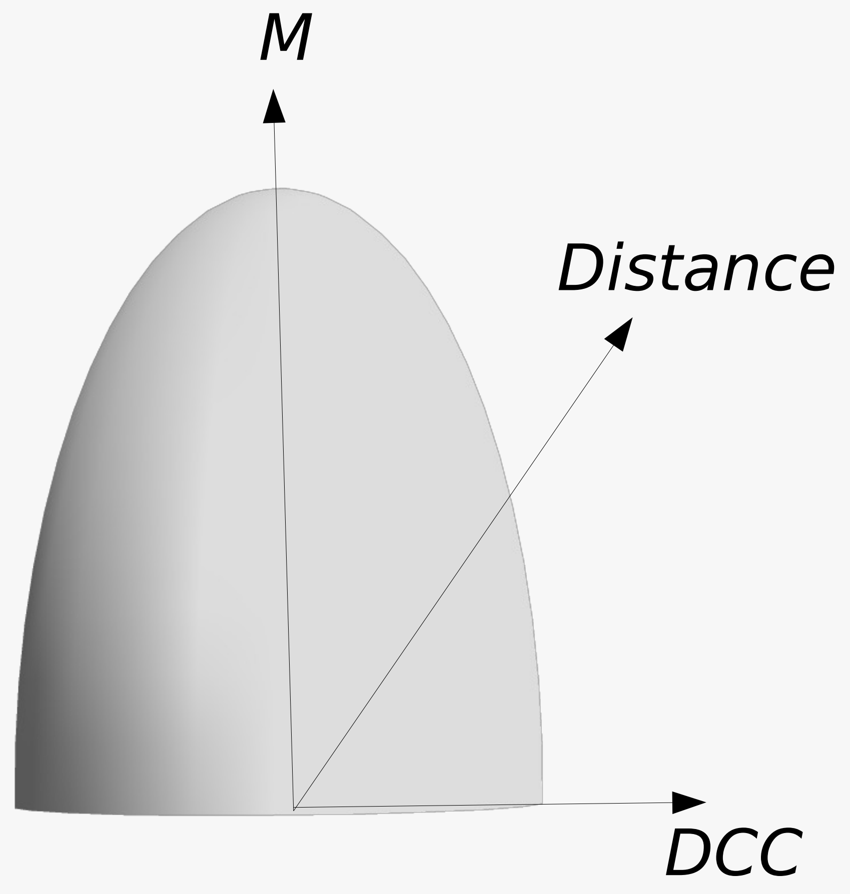
Non-linear model

Radial Basis Functional Neural Network

$$f = \exp\left(\frac{-b\|x-u_k\|^2}{2\partial_k^2}\right)$$

$$M = \sum_{k=0}^{n} af$$





Results

Discussion

		Linear model		Non-linear model	
Scenario	Number of links	Correct link identified	Average time (ms)	Correct link identified	Average time (ms)
1	27	26	4.3	25	21.1
2	27	24	4.4	23	19.3
3	27	23	3.2	22	15.7
4	27	20	3.5	20	14.2

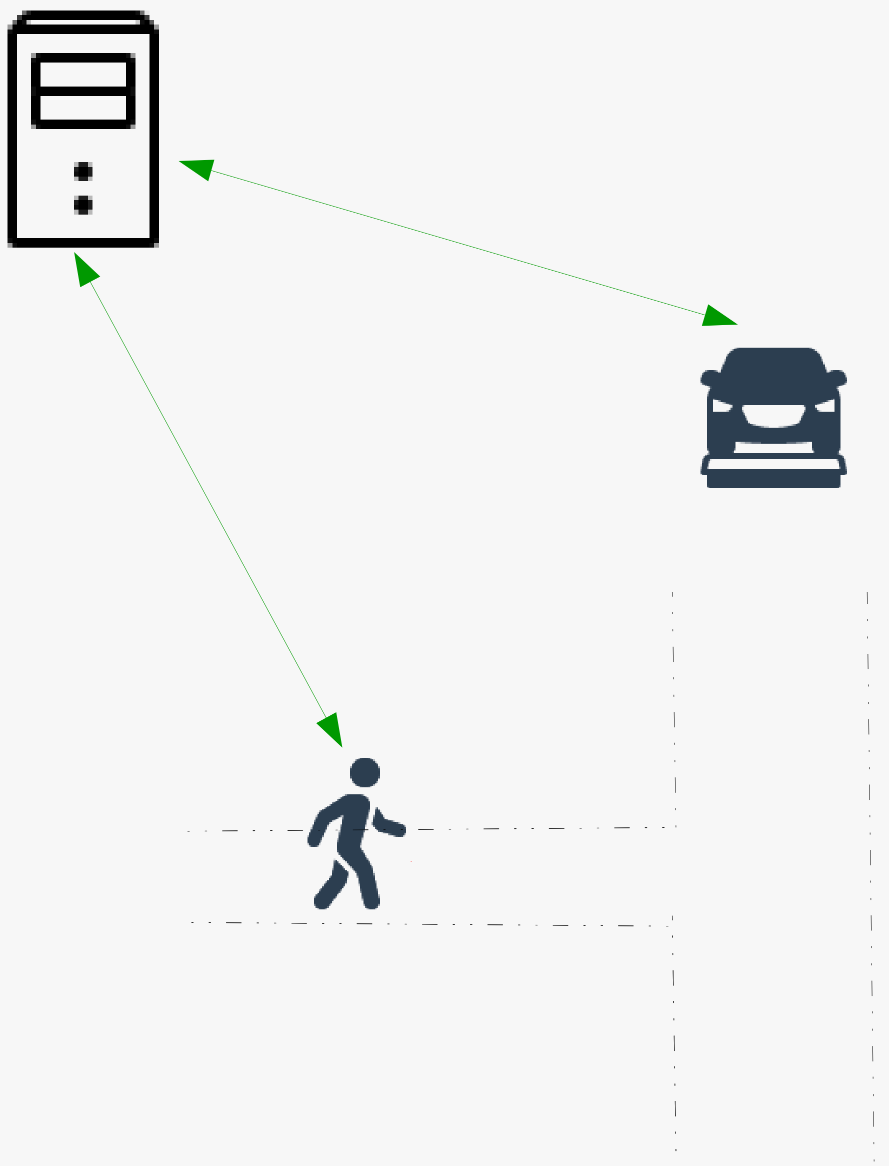
Results

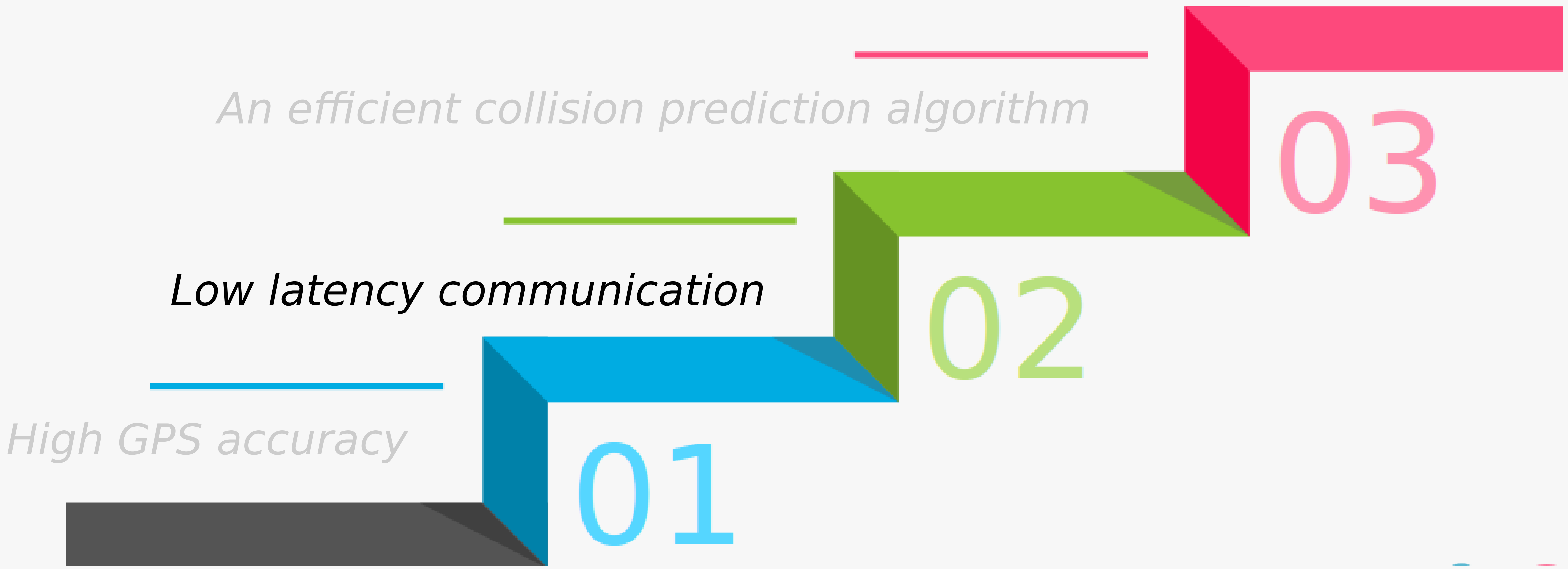
Discussion

		Linear model		Non-linear model	
Scenario	Number of links	Correct link identified	Average time (ms)	Correct link identified	Average time (ms)
1	27	26	4.3	25	21.1
2	27	24	4.4	23	19.3
3	27	23	3.2	22	15.7
4	27	20	3.5	20	14.2

Challenges

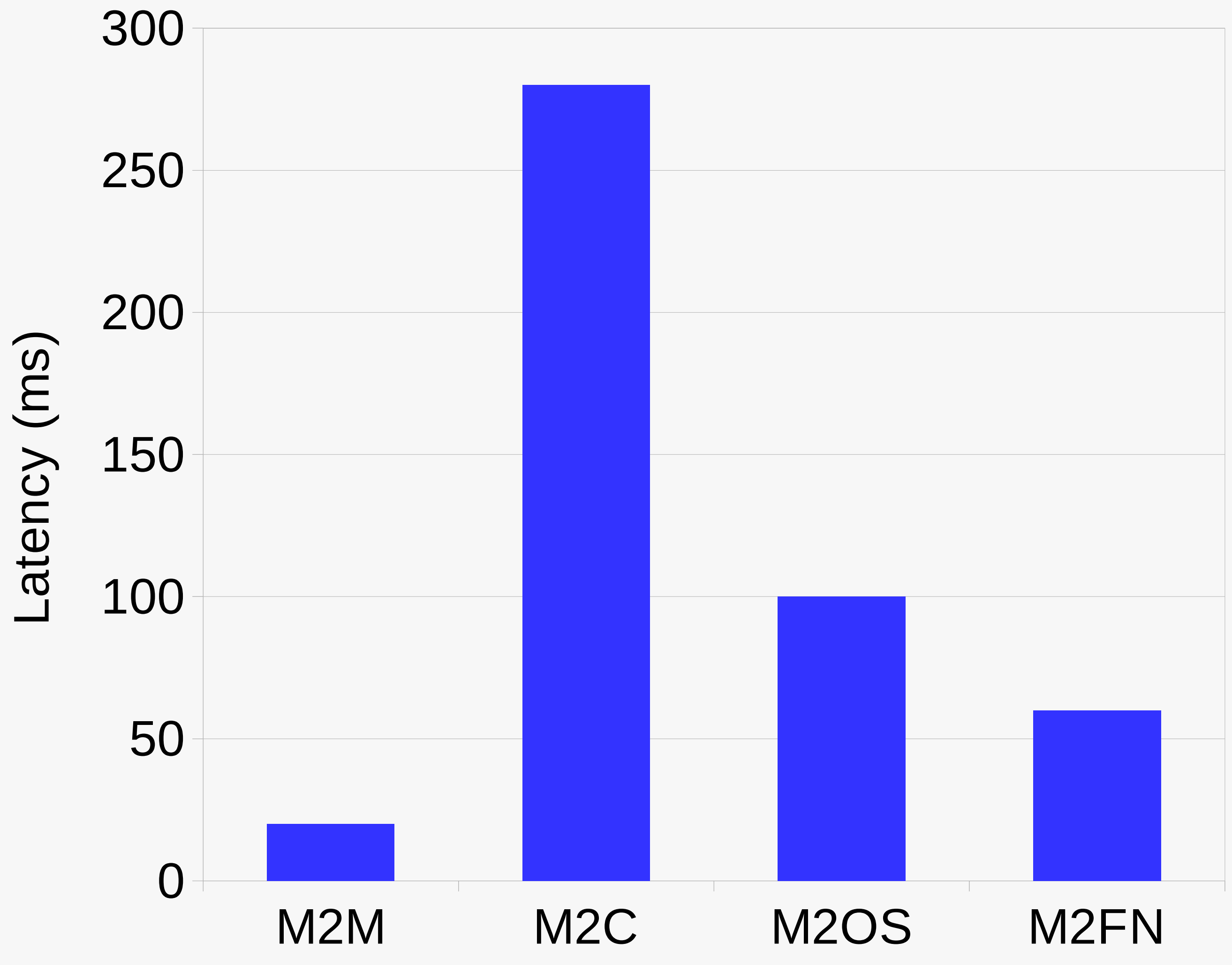
Vulnerable road users alert system





Fog computing architecture

Different architectures

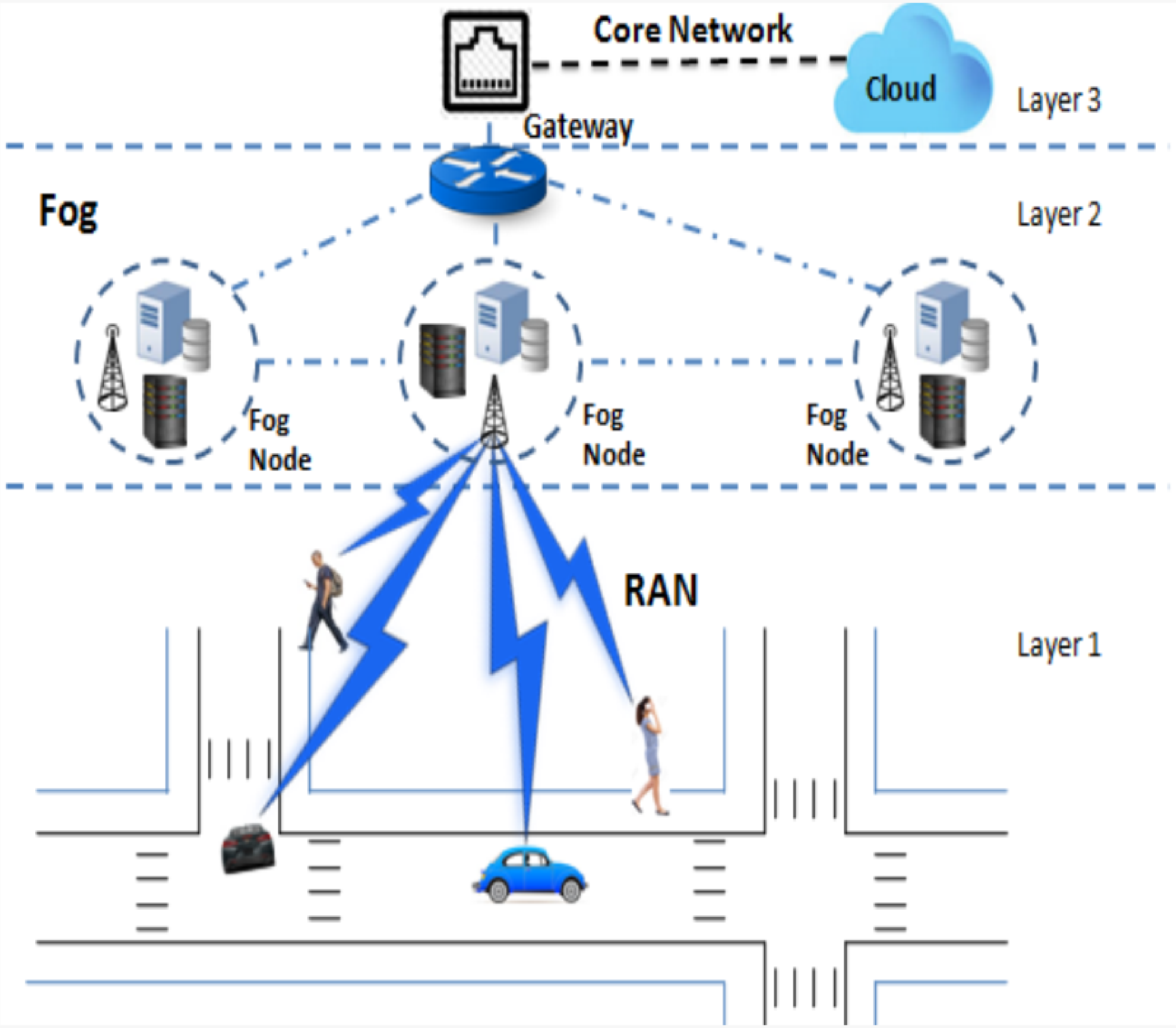


Latency of different smartphone-based VRU safety architectures

Architecture	M2M	M2C	M2OS	M2FN
Energy saving	-	+	+	+
Latency	+	-	+	+
Reliability	+	-	-	+
Scalability	-	+	-	+
Computational capability	-	+	+	+
Message management	-	+	+	+

Fog computing architecture

3 layers architecture



3 Layers:

1) Crowd

- Refers to pedestrians and drivers

- Data is sent to fog node every second

2) Fog node

- Execute the collision prediction algorithm

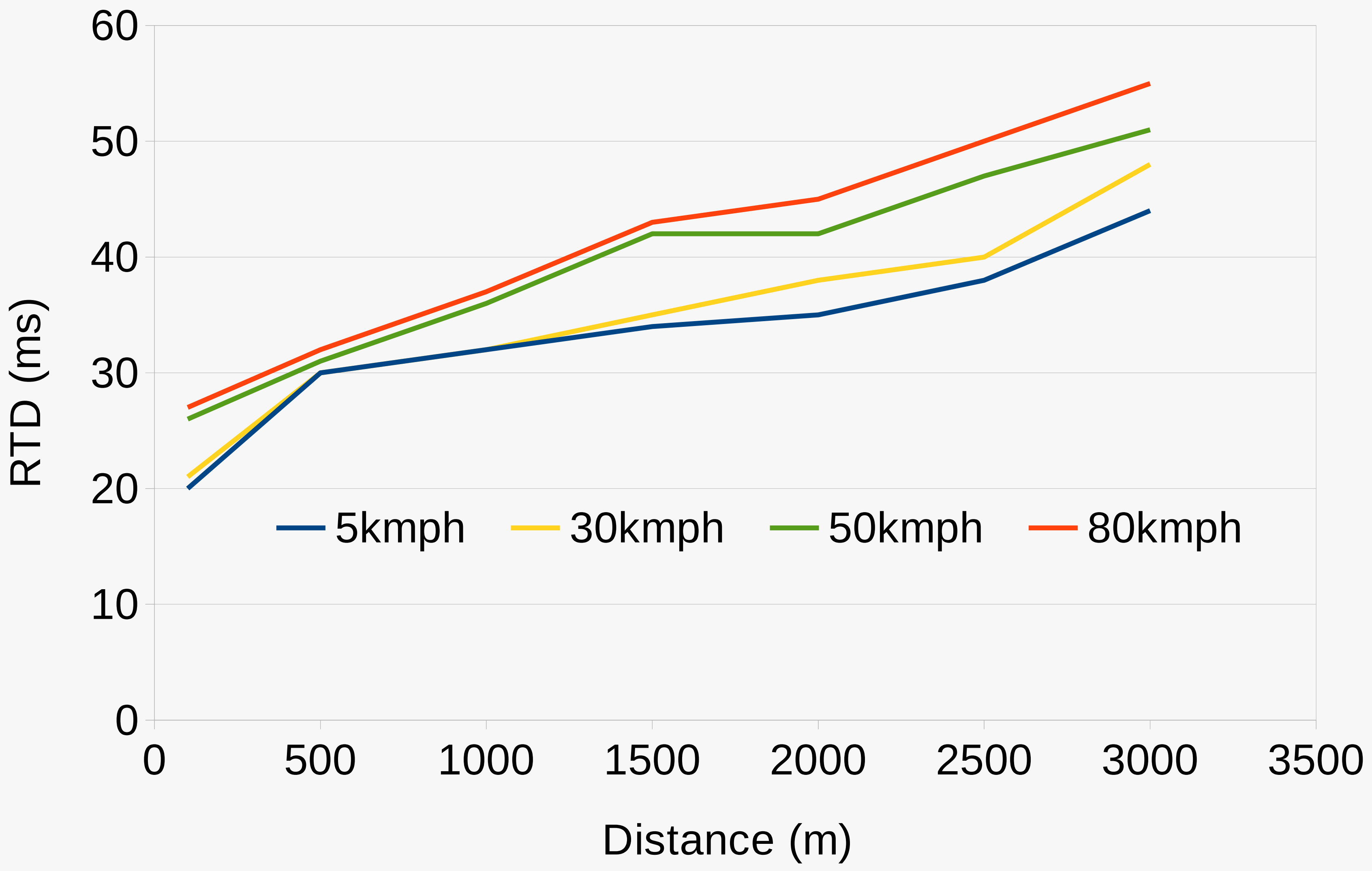
- Road segment covered by a single node depends on the communication technology used

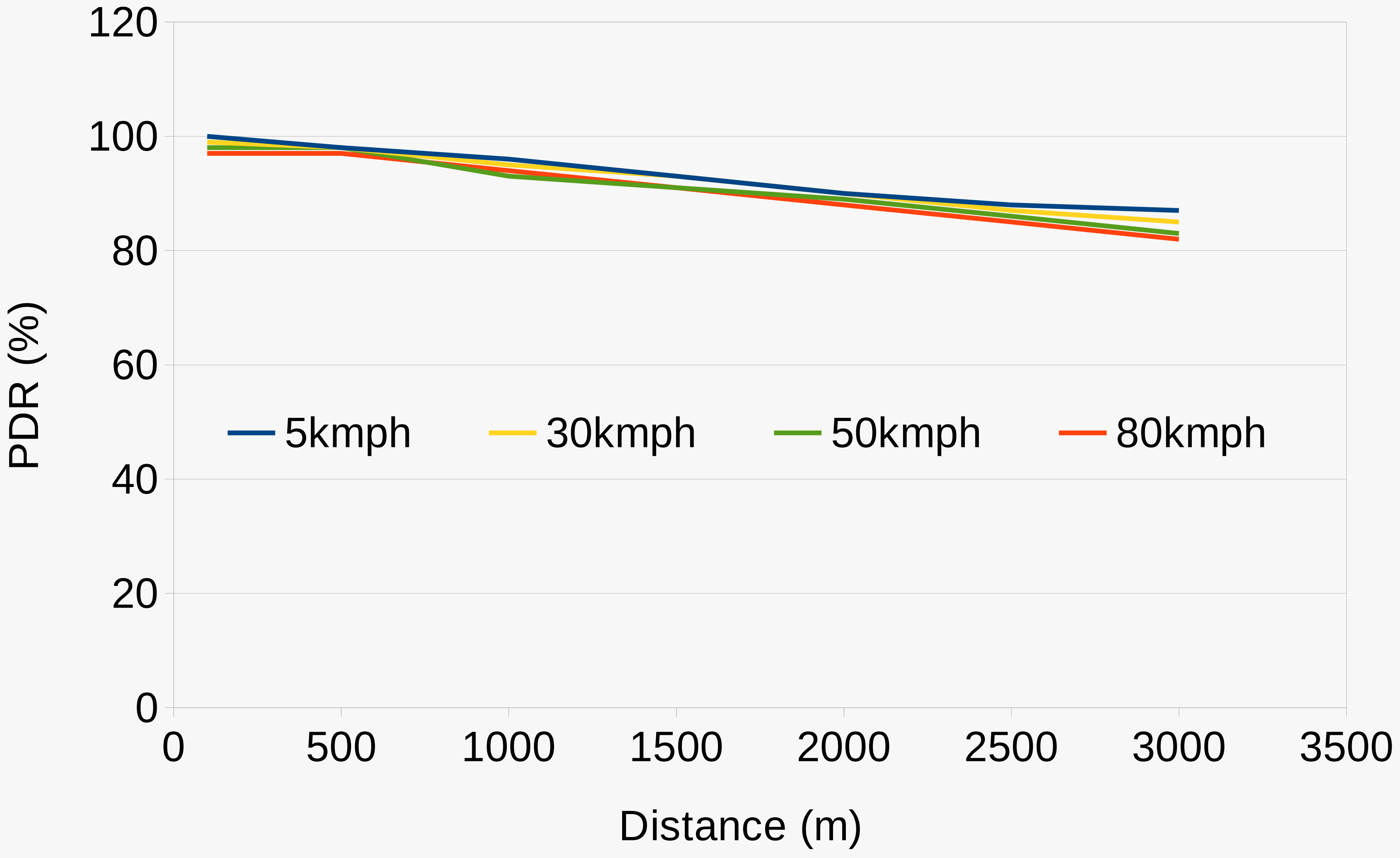
3) Cloud

- Performs aggregated analysis on data received from fog nodes for further use

LTE connection with the fog node

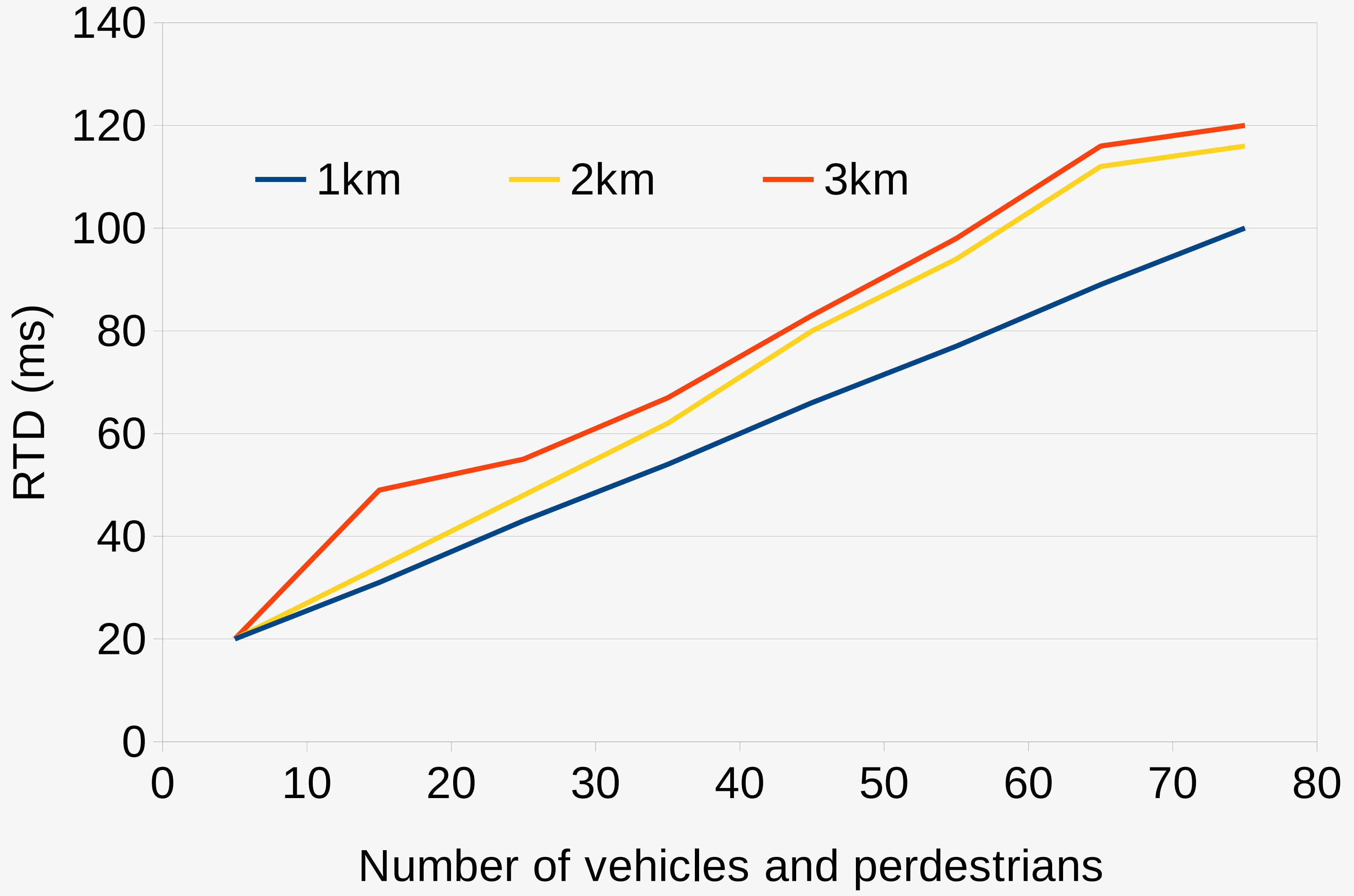
High mobility support of LTE

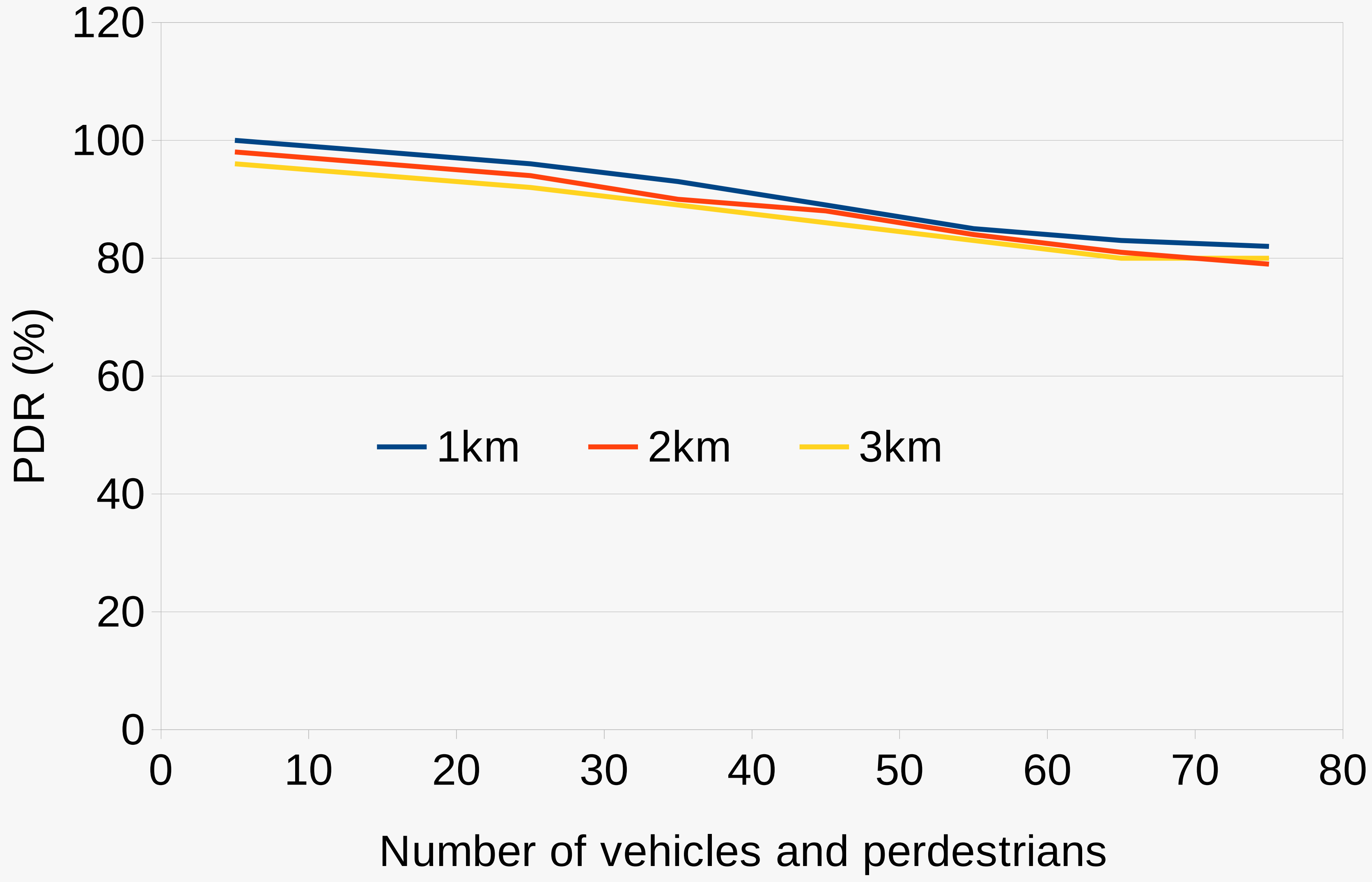




LTE connection with the fog node

Scalability of LTE





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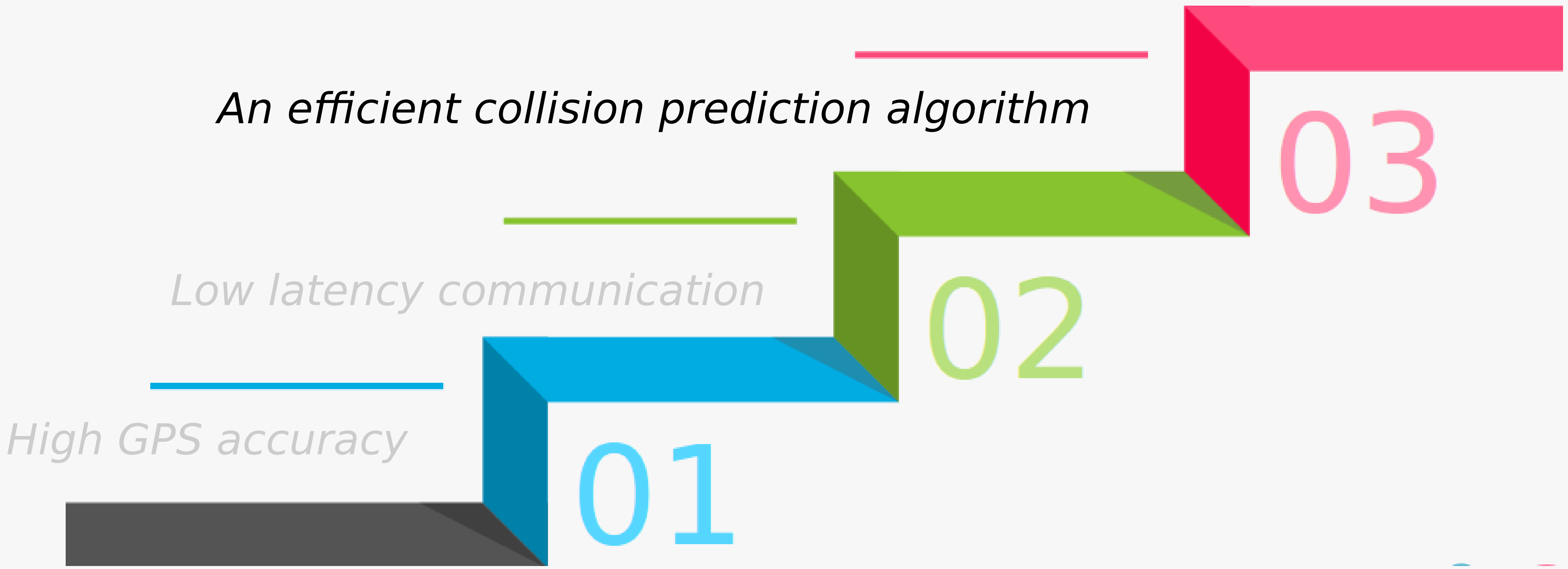
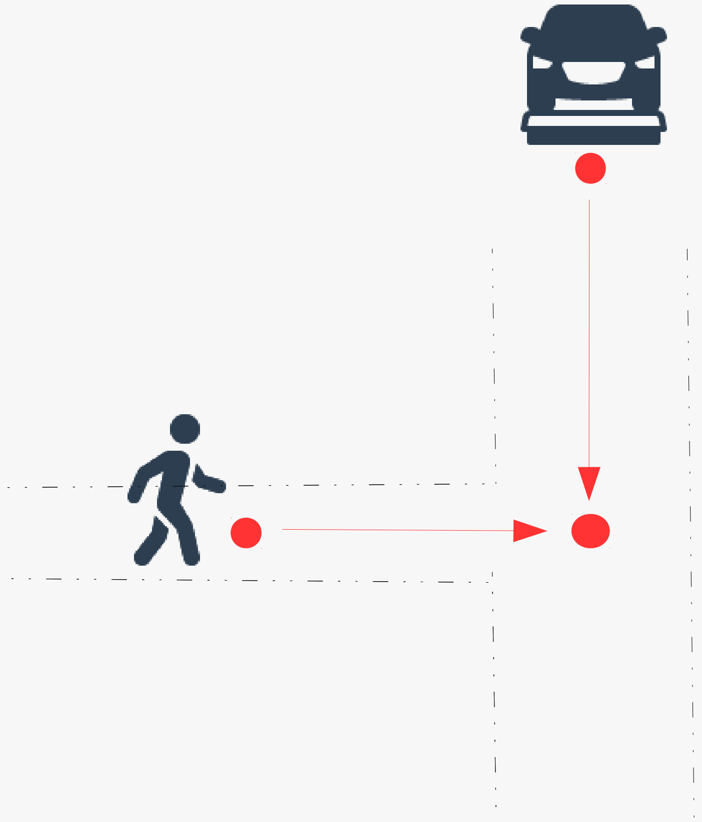
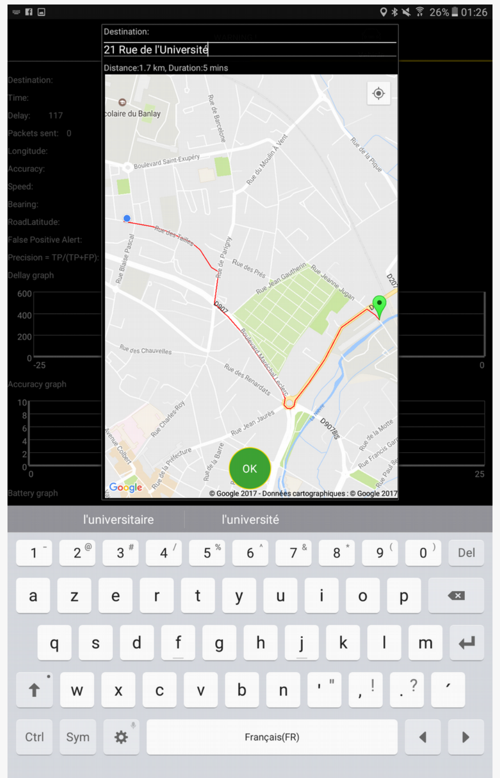
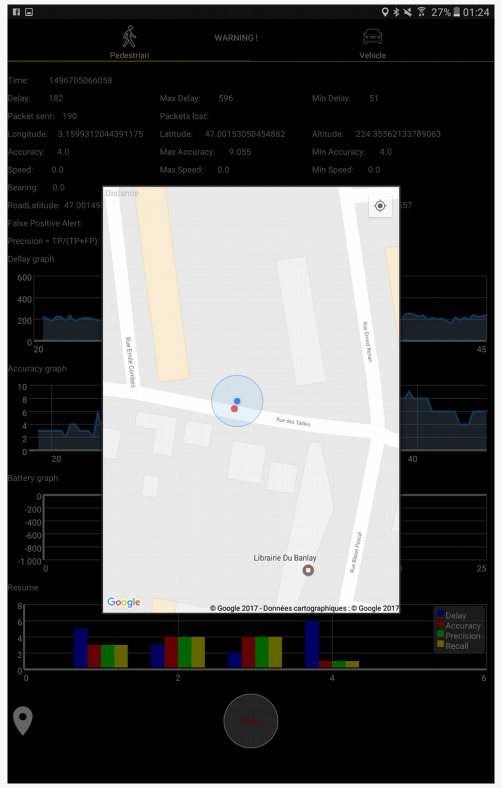


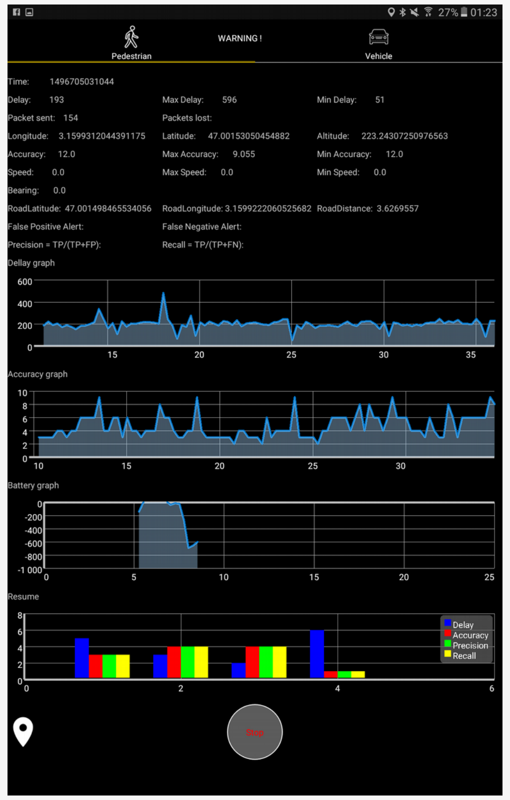


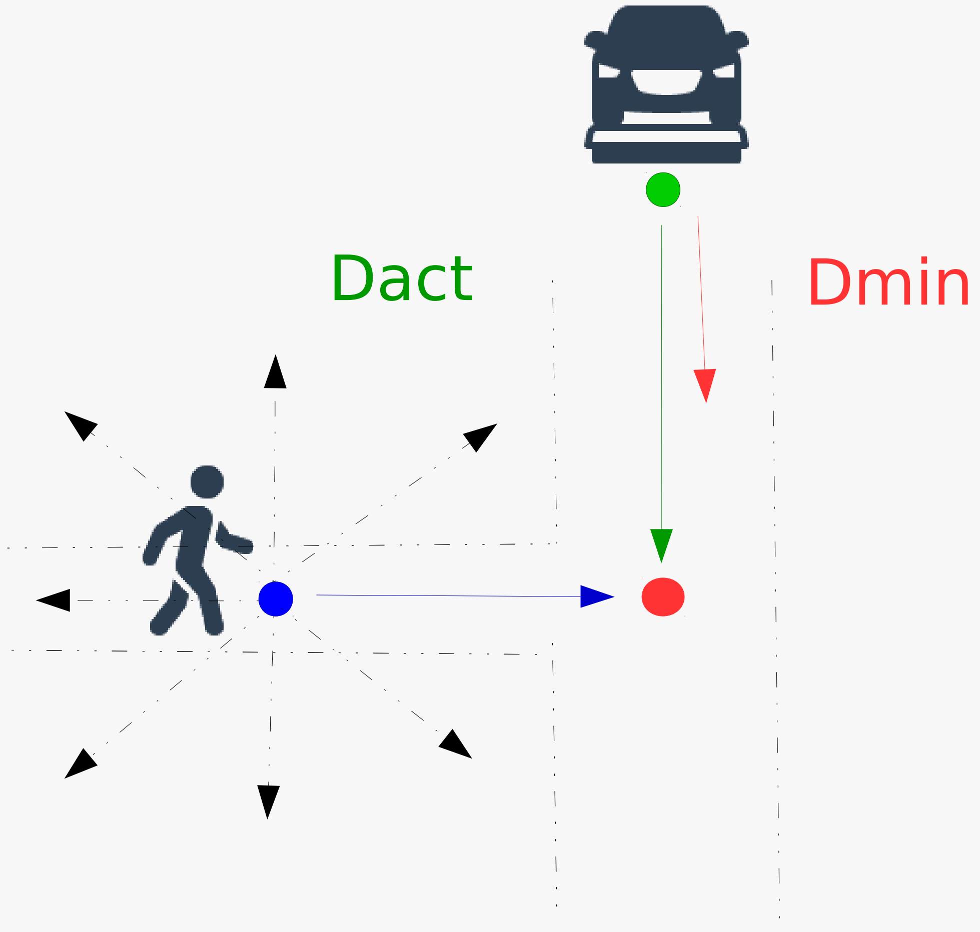
Application

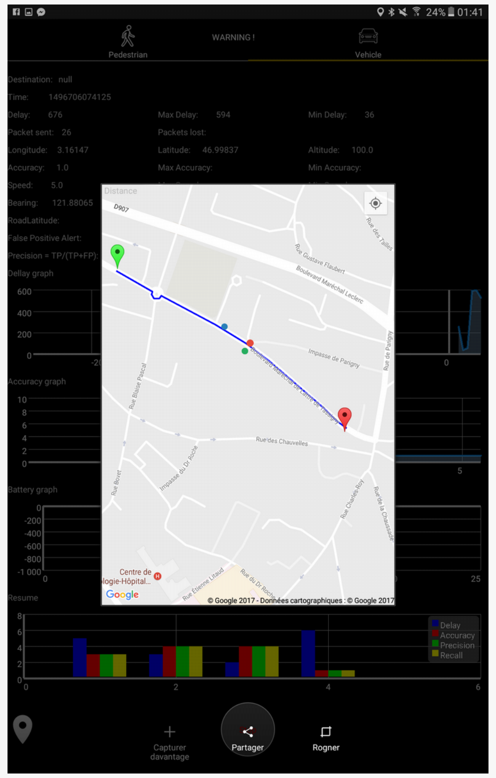
Real environment

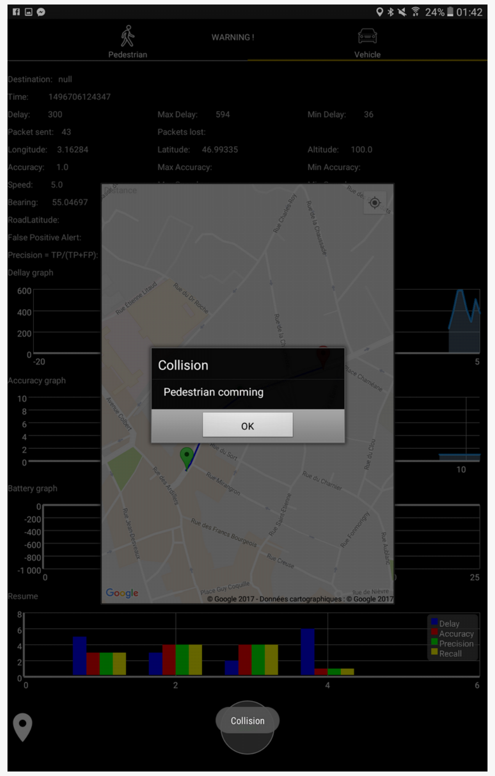


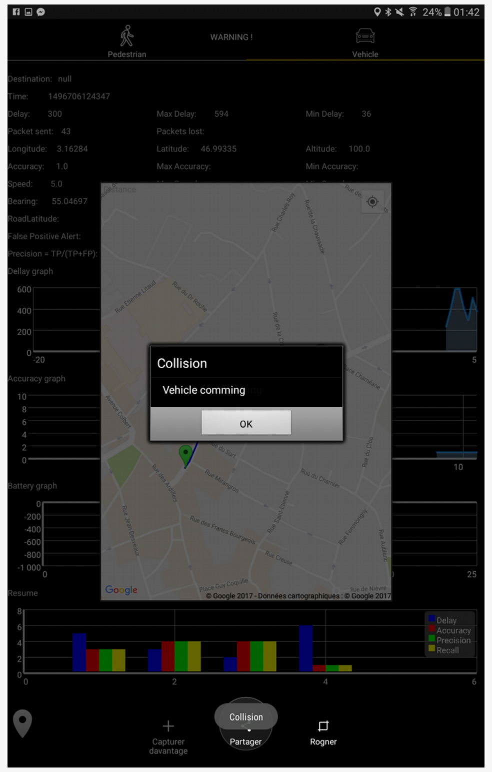










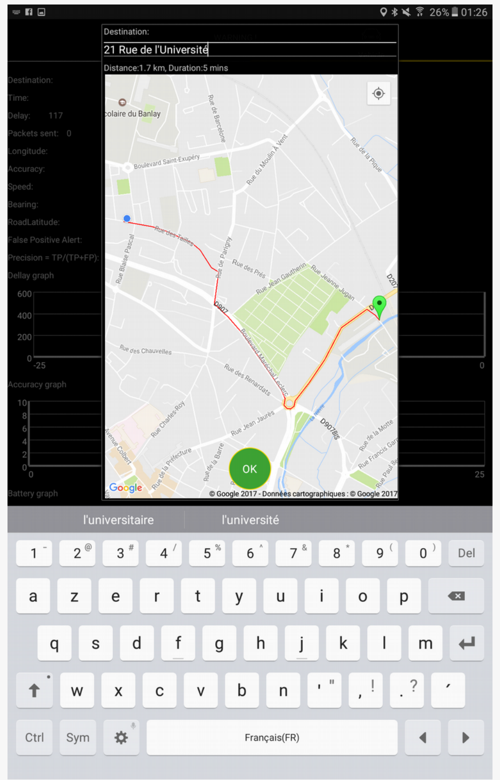


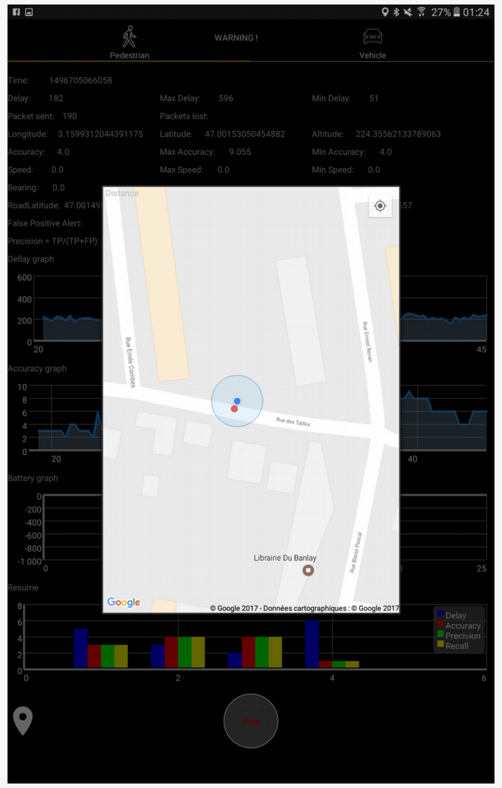
Algorithm:

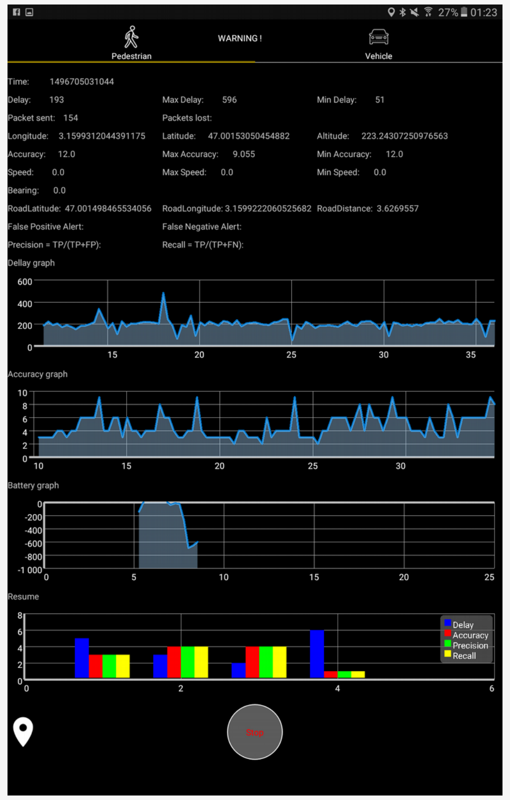
$$Dmin = V\_veh * (T\_p + T\_r + T\_tx + T\_c) + GPS\_{err\text{-}veh} + GPS\_{err\text{-}ped}$$

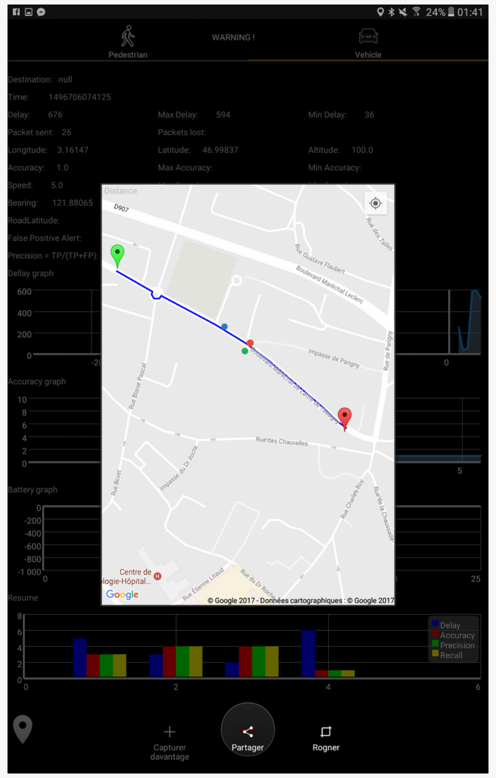
Application

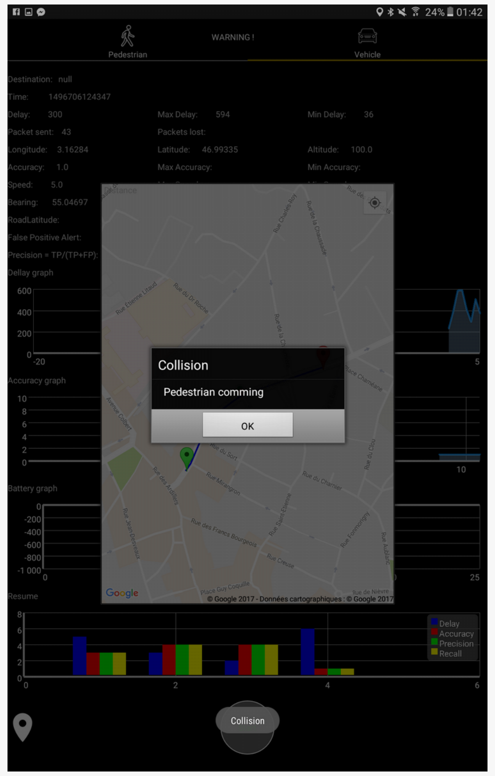
Real environment

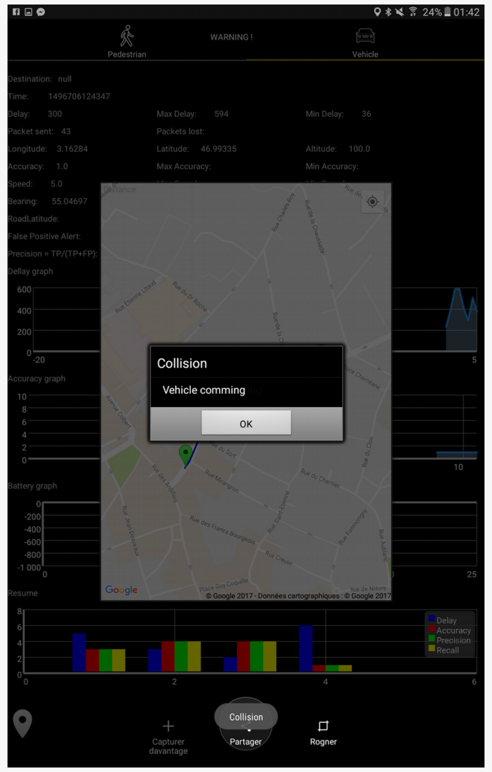


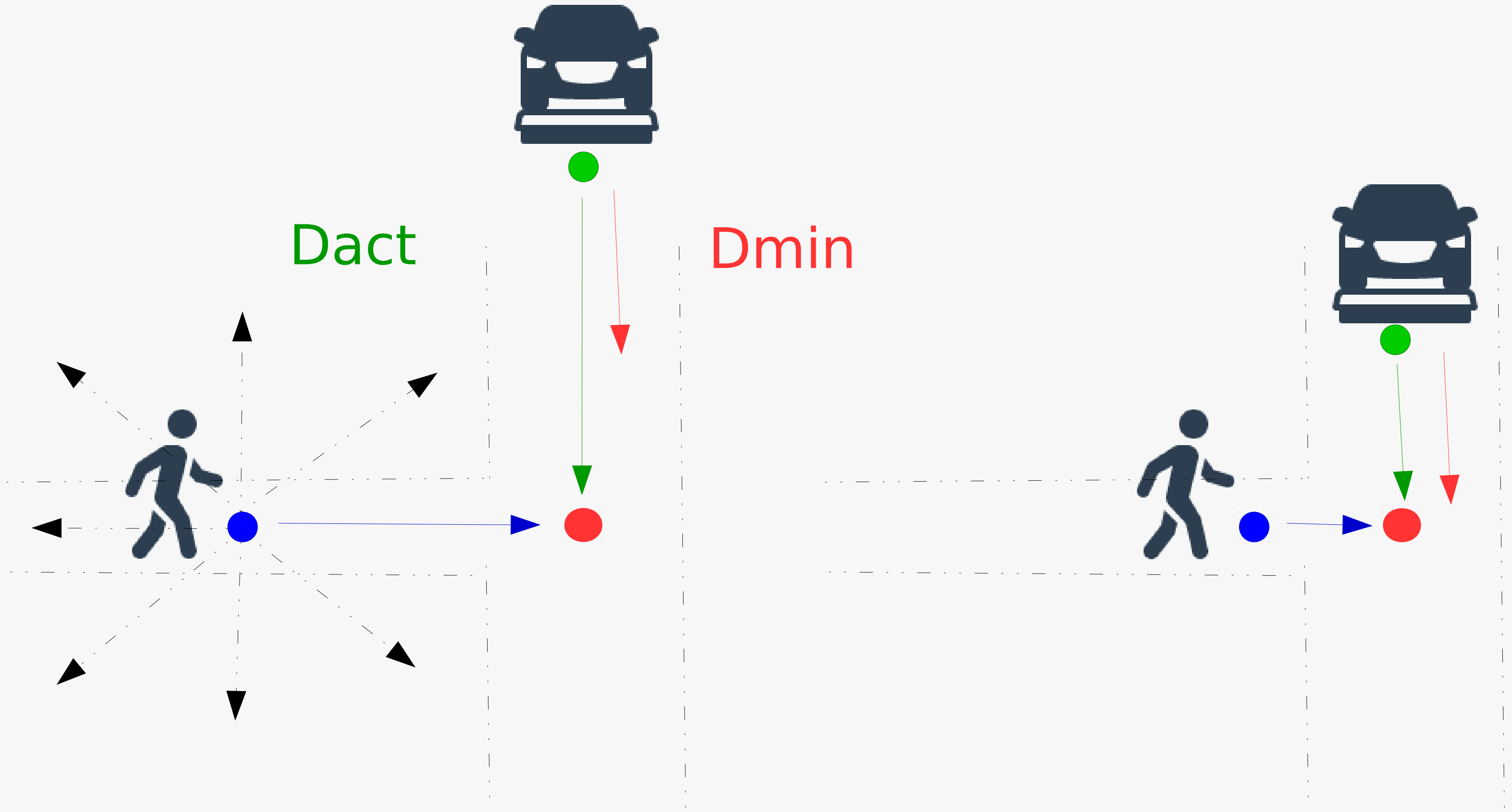












Algorithm:

$$Dmin = V\_veh * (T\_p + T\_r + T\_tx + T\_c) + GPS\_{err\text{-}veh} + GPS\_{err\text{-}ped}$$

$$IF\ (Dact \leq Dmin)\ send\ Alert\ \ WARNING$$

Conclusion

***1) Map matching algorithm** with eight direction chain-code is easily applicable to car navigation and pedestrian navigation.*

***2) Fog computing architecture** is a promising solution for problems that require low latency, high geographical distribution and high mobility support such as pedestrian collision prediction.*

***3)** Delay difference between fast-moving vehicles and slow-moving vehicles is not significant due to high mobility support of **LTE**.*

Future work:

***1)** Adding new parameters in map matching algorithm that impact direction identification such the **signal strength** of each GPS point.*

***2)** Evaluating the efficiency of **map matching algorithm** and **Fog computing architecture** with **LTE connection** to reduce false positive alerts.*

Thank You For Your Attention !

Any Questions ?

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