# Robust Positioning for Urban Traffic

## Motivations and Activity plan for the WG 4.1.4

Dr. Laura Ruotsalainen
Research Manager, Department of Navigation and positioning

Finnish Geospatial Research Institute (FGI)
National Land Survey

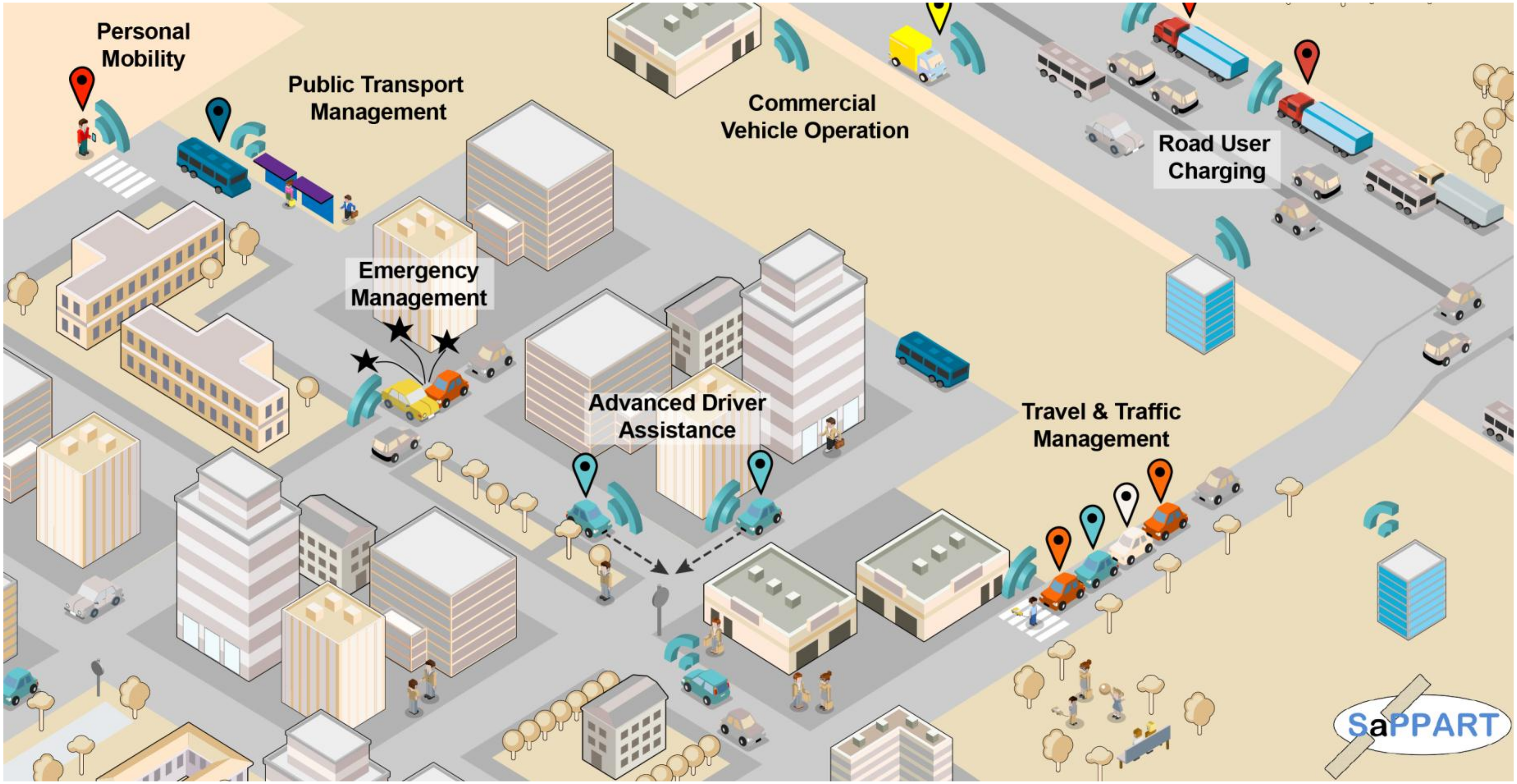
NLS FINNISH GEOSPATIAL RESEARCH INSTITUTE FGI

# WG’s Motivation

- The Work Group will focus on the navigation challenges on the urban environments for greener, safer and more comfortable traffic.
- Chair: Laura Ruotsalainen, Finnish Geospatial Research Institute (Finland)
- Vice-Chair: Fabio Dovis, Politecnico di Torino (Italy)
- WG has attracted so far >10 scientists around the world (Europe, Canada, China)

NLS FINNISH GEOSPATIAL RESEARCH INSTITUTE FGI

# Urban traffic – extensive positioning requirements

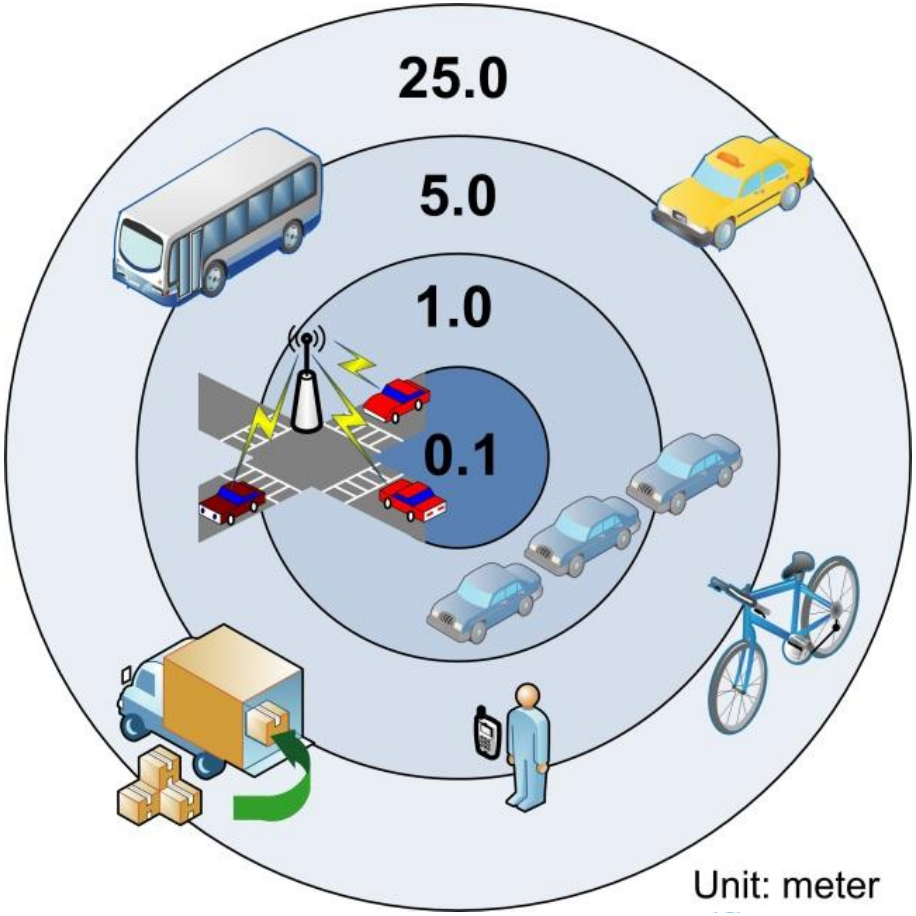



Peyret, F. et al. (2015) COST TU1302- SaPPART White Paper - Better use of Global Navigation Satellite Systems for safer and greener transport

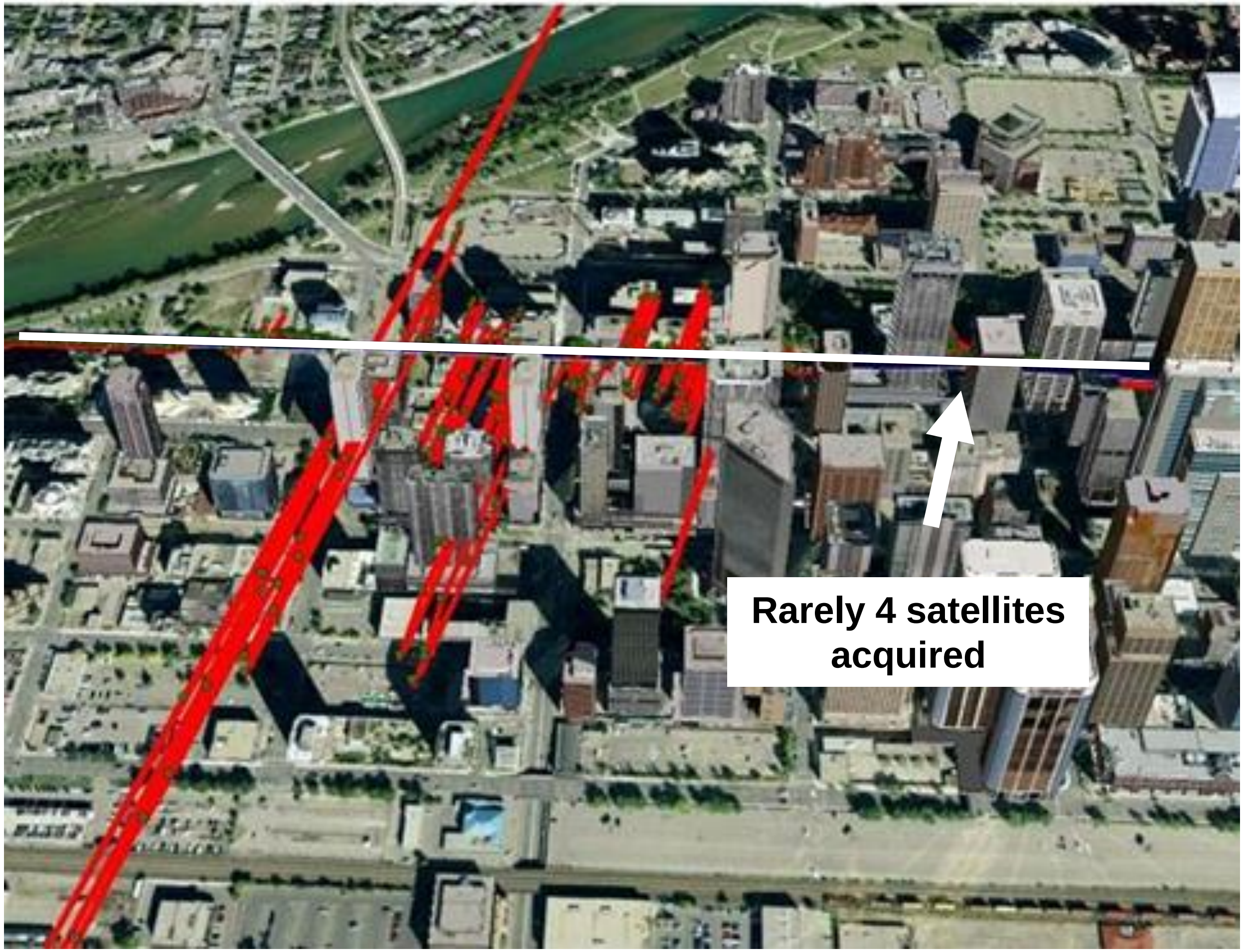
NLS FINNISH GEOSPATIAL RESEARCH INSTITUTE FGI

# Challenges in urban traffic

- Global Navigation Satellite Systems (GNSS) provide good performance in open outdoor environments
- Navigation solution with sufficient accuracy and integrity is needed in urban canyons, where GNSS is significantly degraded or unavailable
- A suitable set of other methods for augmenting or replacing the use of GNSS in positioning for urban traffic is needed



# Challenging environments (1)




White = true path, Green = GPS positions, Red = Path with GPS

Urban canyons, degraded accuracy and availability due to signal obstruction and multipath

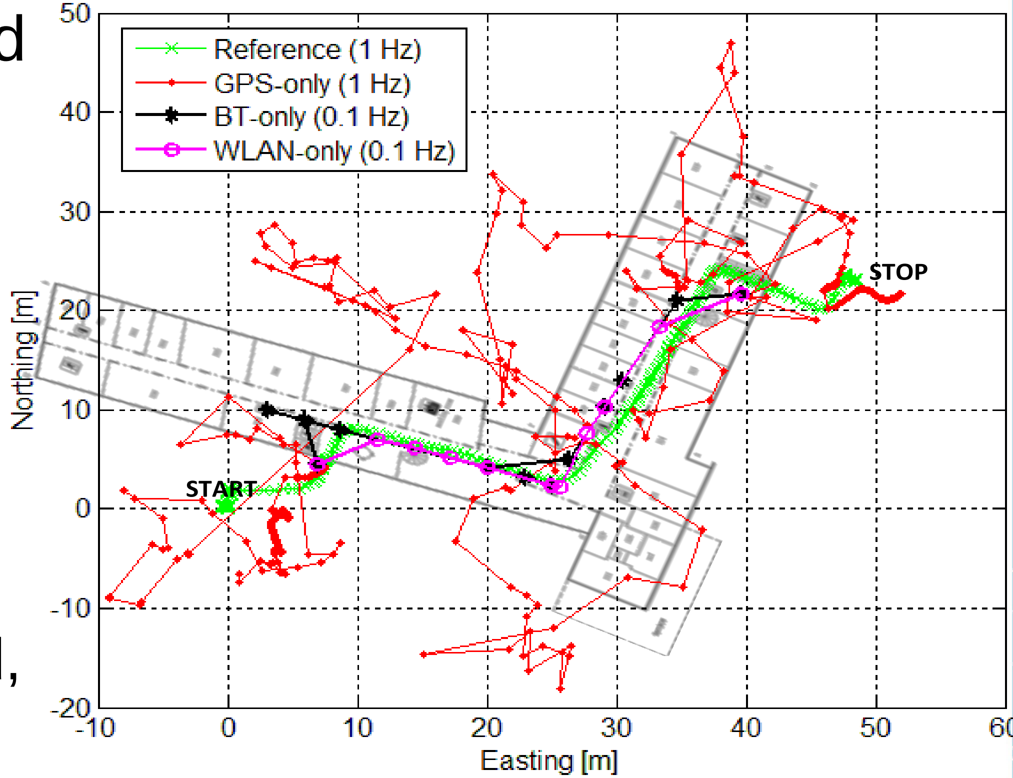
- Figure: Calgary downtown
- In Helsinki downtown also deep urban canyons

Ruotsalainen, Vision-aided Pedestrian Navigation for Challenging GNSS Environments, Doctoral dissertation, 2013

NLS FINNISH GEOSPATIAL RESEARCH INSTITUTE FGI

# Challenging environments (2)

- Indoors (parking halls etc) GNSS is heavily degraded or not available at all
  - E.g. concrete and steel fade the signal extensively, depending on the elevation angle of the satellite
  - Although High Sensitivity GNSS (HSGNSS) is used, reliability and accuracy is degraded



# Work Group's major focus

- Specification and characterization of the system requirements, especially from the environmental and safety viewpoints
- Usability of emerging technologies, including vision-aiding and collaborative driving systems
- Selection of best set of technologies fulfilling the system requirements
- Performance analysis of the selected system both for vehicles and pedestrians in urban areas
- Most suitable algorithms for map matching and routing

NLS FINNISH GEOSPATIAL RESEARCH INSTITUTE FGI

# Sensor and radio data fusion to GNSS

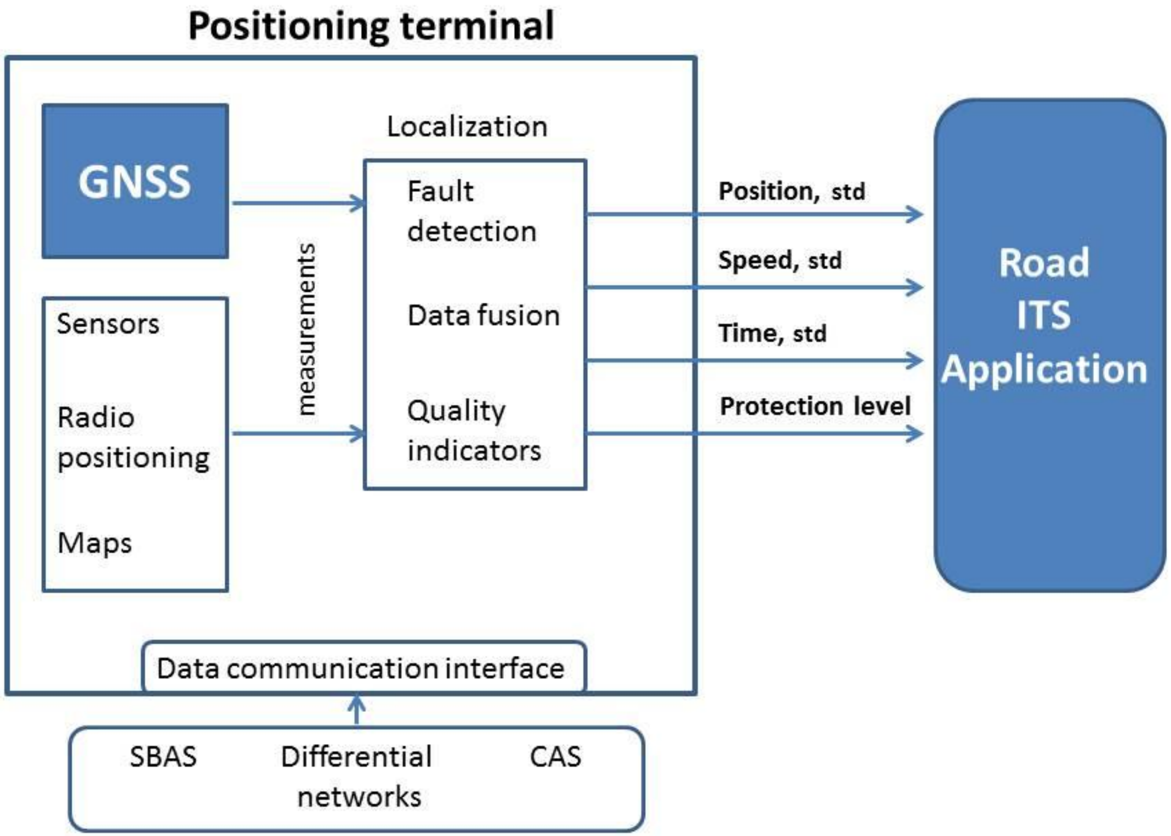
- Sensors are immune to usual GNSS problems
  - Signal blockage
  - Multipath
  - Jamming
- Provision of position and velocity at a higher rate (400 Hz / 1 Hz)
- Complementary information, such as acceleration and attitude
- Redundant positioning estimates coming from different sources

➢ improved accuracy and precision, robustness and reliability

NLS FINNISH GEOSPATIAL RESEARCH INSTITUTE FGI

# Methods addressed by WG

- Multi-GNSS / multi-sensor / multi-radio
- Different sensors and methods
  - INS, odometer
  - Vision, Lidar
  - WiFi, RFID
- Integration algortihms
  - Error modelling
- Cooperative systems
- Crowdsourcing
- Map-matching

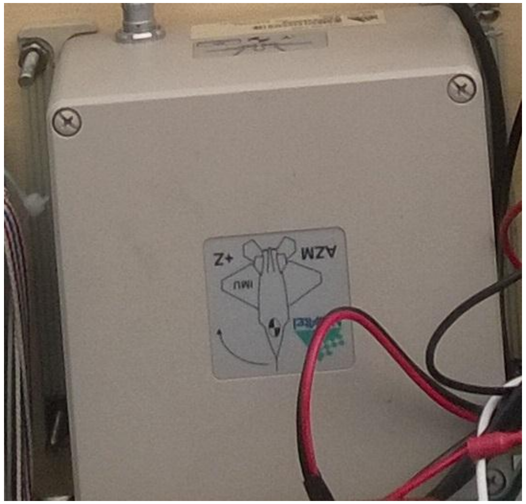



Peyret F. (2013) Standardization of performances of GNSS-based positioning terminals for ITS applications at CEN/CENELEC/TC5

NLS FINNISH GEOSPATIAL RESEARCH INSTITUTE FGI

# Inertial and other self-contained sensors for urban traffic

- Inertial Navigation System
  - Accelerometer providing acceleration
  - Gyroscope providing angular velocity
  - ➢ Relative position information to be integrated with GNSS
- ➢ Magnetometers, odometers, barometers, …
- ➢ Suffer from measurement errors that degrade the solution




# Camera for urban traffic (1)

- Camera-based positioning emerging rapidly
  - Accurate
  - Increase in data transmission rates and computational capabilities of processing equipment
  - Development of algorithms in image processing
- Cameras equipping more and more frequently the new vehicles => very low additional cost.
- Methods may be divided into self-positioning systems / surveillance systems
- Methods based on database / consecutive images
- High sensitivity to the weather and light conditions

# Camera for urban traffic (2)

- A database of images acquired with the camera with the "true" trajectory
  - the system compares the actual images with the stored ones and determines from this matching the deviation from the recorded trajectory and consequently its position
  - Has demonstrated impressive positioning performances in terms of *Accuracy* in many R&D projects
- Consecutive images may be used as additional inertial sensors
  - "visual gyroscope" and "visual odometer" => heading change and translation computed between consecutive images

Ruotsalainen (2013) Vision-aided pedestrian navigation for challenging GNSS environments, Doctoral dissertation

# Lidar for urban traffic

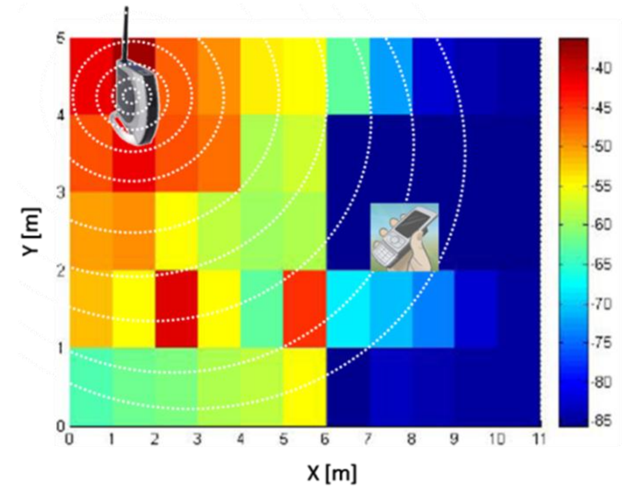
- LIght Detection And Ranging (LIDAR) has high accuracy in ranging, wide area view and low data processing requirements
- Transmitting a laser pulse and calculating distance to surrounding constructions based on the signal return time
- Suffers from noise => reliability is highly dependent on the distance and reflectivity of different objects
- Robust to light conditions
- Increasingly found in vehicles, mainly for obstacle detection but sometimes also for positioning
- Cost a significant drawback

# Rfid for urban traffic

- Radio Frequency Identification (RFID) is a wireless radio technology
- Provides information about RFID tag's proximity, carried by the user, to the RFID reader => requires infrastructure
- Usually implemented on gateways to provide information about the traffic in the area
- Can be used locally as complementary positioning technology in some specific points like tunnels by GNSS-based tolling systems
- Positioning performance is dependent on the RFID technology used for the implementation and of the density of the tags network

# WiFi for urban traffic

- Wireless networks Positioning has become popular in recent years especially in dense urban and indoor environments
- Positioning can be performed using different types of measurements, the most common being:
  - signal power measurements, e.g. Received Signal Strength (RSS)
  - angle to transmitter measurements, e.g. Angle of Arrival (AoA)
  - propagation time measurements e.g. Time of Arrival (ToA), Time Difference of Arrival (TDoA), Differential Time Difference of Arrival (DTDoA)



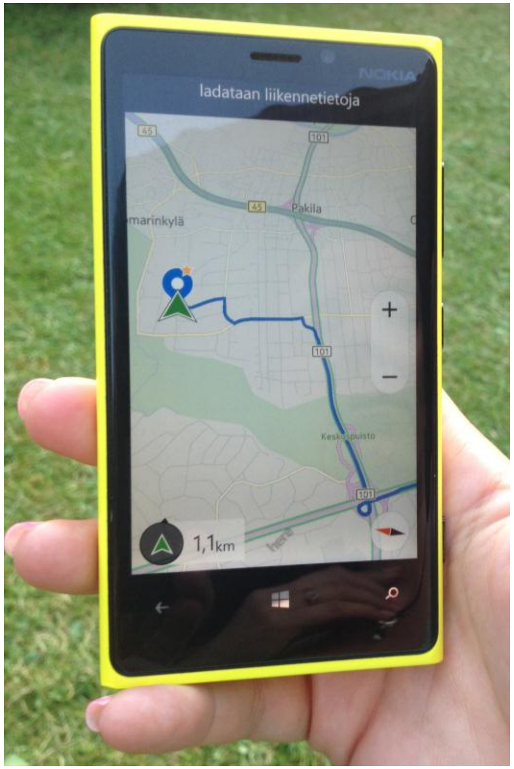

NLS FINNISH GEOSPATIAL RESEARCH INSTITUTE FGI

# Available WiFi Access points in Helsinki downtown


RESEARCH INSTITUTE FGI

# Pedestrians

- For pedestrians sensors have to be
  - Low-cost
  - Light weight
  - Small
  - ➢ MEMS sensors / smartphones, large errors
- Monocular camera
- More freedom in dynamics and route




NLS FINNISH GEOSPATIAL RESEARCH INSTITUTE FGI

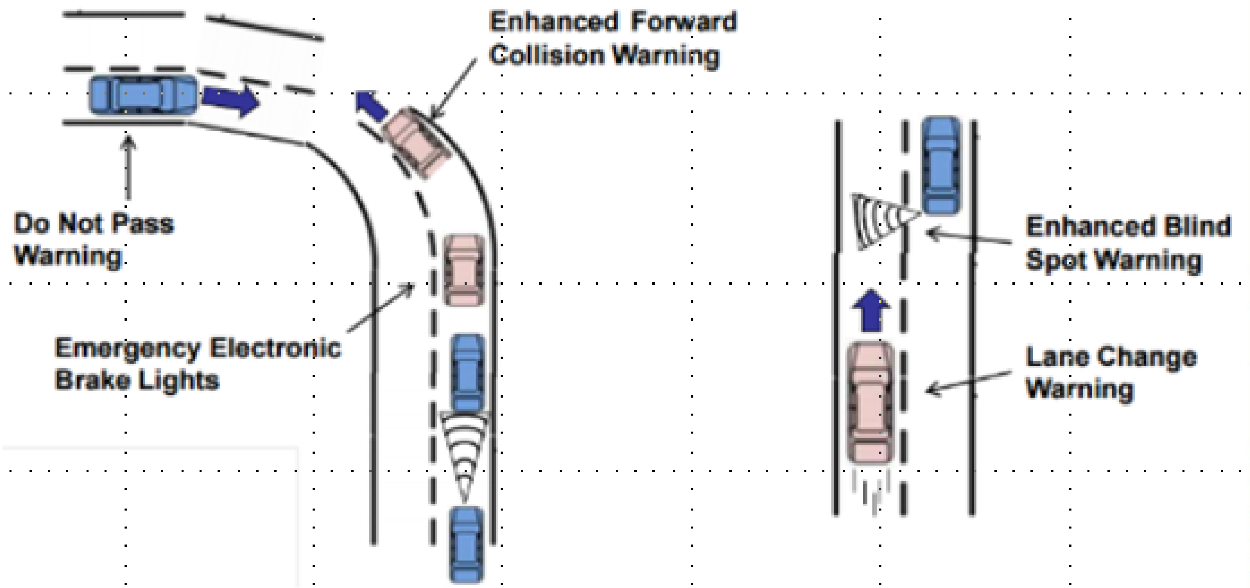
# Map Matching

- Use of 2D map data as constraints in the data fusion process
  - map information is used by the data fusion algorithm to constraint the solution (the vehicle is assumed to be on the road)
  - ➢ converge towards a more reliable solution
- Use of 3D map data to improve the raw measurements data quality
  - knowledge of the 3D environment (mainly the buildings) is used to analyse the propagation conditions of the satellite signals
  - ➢ qualify and correct the pseudorange observables

NLS FINNISH GEOSPATIAL RESEARCH INSTITUTE FGI

# Cooperative positioning (1)

- Peer-to-peer and cooperative positioning bring together capabilities of Satellite Navigation and Communication Systems
- Vehicle to Vehicle (V2V) communication
  - safe distance keeping
  - collision avoidance
  - early warning of unsafe conditions
  - ➢ safer transport




Picture: USDOT

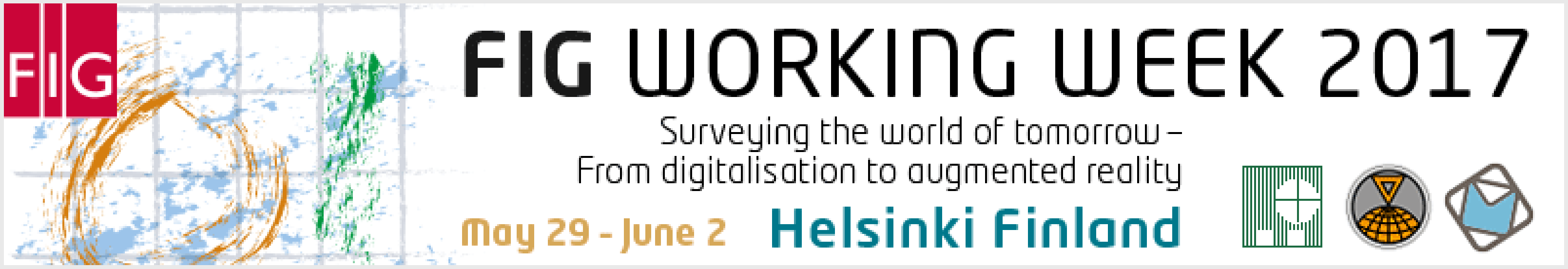
# Cooperative positioning (2)

- Vehicle to Infrastructure (V2I) communication
  - improved information regarding travel times
  - roadwork presence
  - weather and traffic conditions
  - up-to-date information about parking availability or other means of transport.
  - ➢ better use of the existing infrastructure
- ➢ Data may be collected via crowdsourcing from other users


NLS FINNISH GEOSPATIAL RESEARCH INSTITUTE FGI

# Establishing links between the outcomes of this WG (1)

- Other IAG and FIG WGs
  - Other IAG WGs hopefully here




  - Working week 2017 arranged by my organization
- Institute of Navigation (ION)

NLS
FINNISH GEOSPATIAL RESEARCH INSTITUTE
FGI

# Establishing links between the outcomes of this WG (2)

- EU COST action Satellite Positioning Performance Assessment for Road Transport (SaPPART) www.sappart.net
- Action ongoing 2013-2017
- Valuable information and contacts brought into WG 4.1.4
- Joint workshop in 2017?

COST EUROPEAN COOPERATION IN SCIENCE AND TECHNOLOGY

NLS FINNISH GEOSPATIAL RESEARCH INSTITUTE FGI

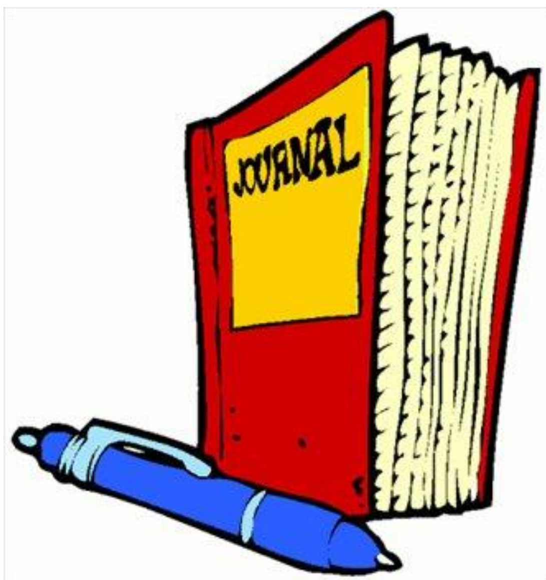
# Establishing links between the outcomes of this WG (3)

- Different actors having interest in urban traffic, e.g. transport authorities, car manufacturers
  - Ertico: ERTICO - ITS Europe is a partnership of around 100 companies and institutions involved in the production of Intelligent Transport Systems (ITS)
  - eKnot: Horizon2020 Research and Innovation Programme for education, research, industry
    - Roadshow, in Torino 2017

NLS FINNISH GEOSPATIAL RESEARCH INSTITUTE FGI

# First joint publication

- Joint publication to the Journal of Sensors Special edition: ”Sensor Technologies and Methods for Perception Systems in Intelligent Vehicle 2017” in December 2016




NLS FINNISH GEOSPATIAL RESEARCH INSTITUTE FGI

# Thank you!

laura.ruotsalainen@nls.fi

NLS
FINNISH GEOSPATIAL RESEARCH INSTITUTE
FGI