TIMON

# Hybrid Communication

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- **Project Overview**
- Hybrid Communication Concepts
- Services Enabled by Hybrid Communication

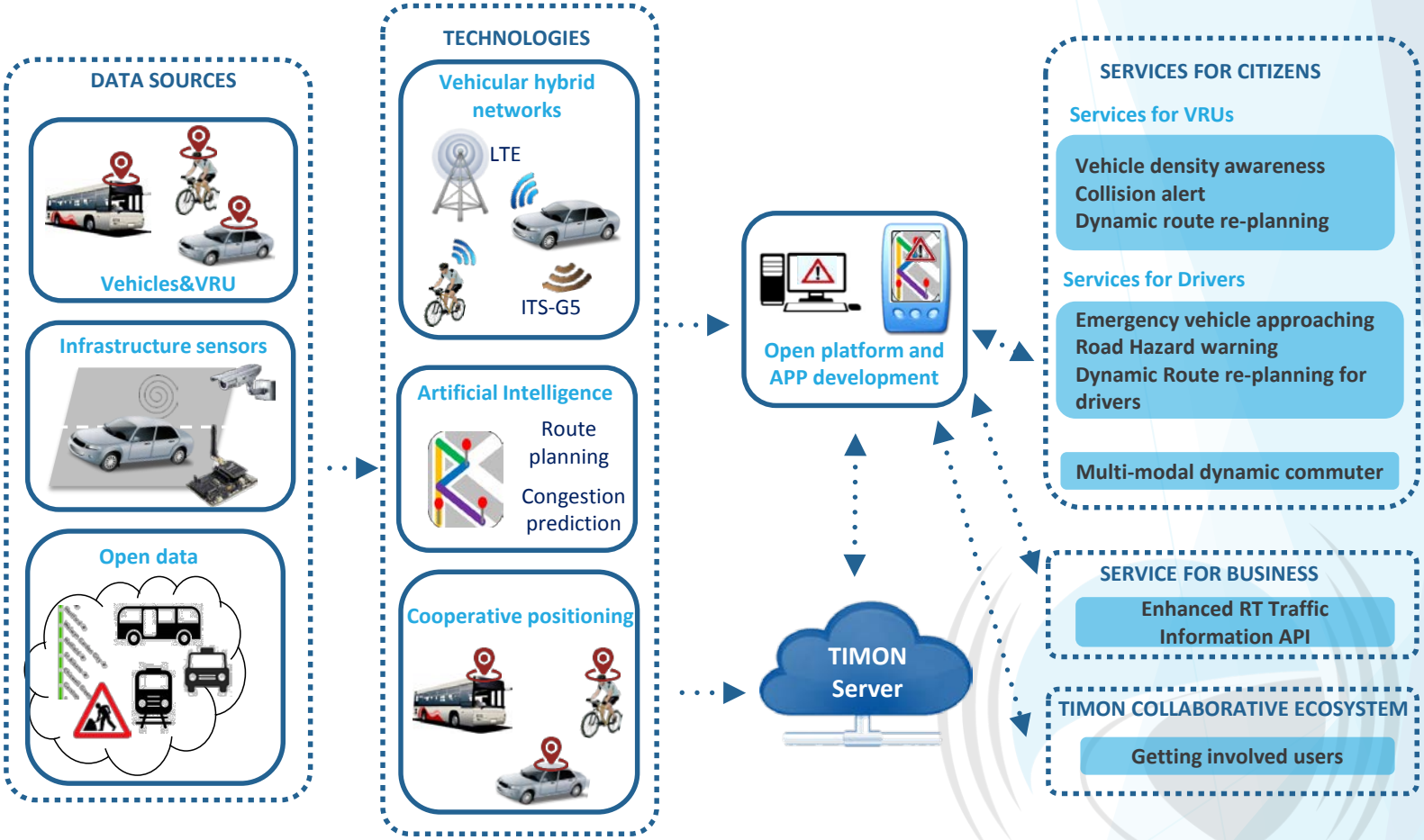
# Project Overview

Enhanced **real-time services** for an optimized **multimodal** mobility relying on **cooperative networks** and **open data**

***TIMON***

- Executed by a consortium of **11 partners at EU level**
- Duration: **42 months (June 2015 - November 2018)**
- Objective:
  - Develop a cooperative **open web-based platform** and mobile application in order **to deliver real-time information and services to drivers, vulnerable road users (VRUs), and businesses**
  - By taking advantage of **cooperative communication** and by processing **open data** related to mobility

# Overall Concept




- ✓ **Increased road safety:** Driver assistance systems based on V2V and V2I, services for VRUs
- ✓ **Flexible and sustainable mobility:** Transport and mobility data from a diverse range of sources for optimized multimodal route planning and congestion prediction

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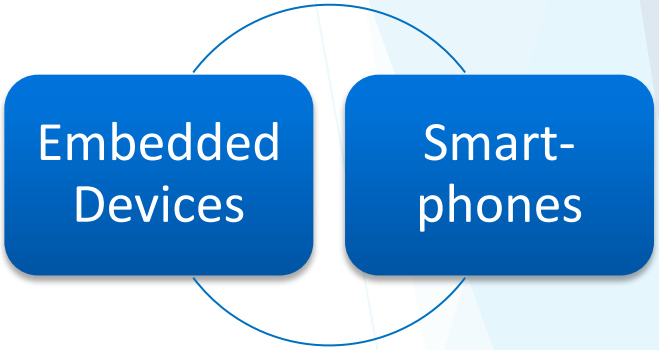
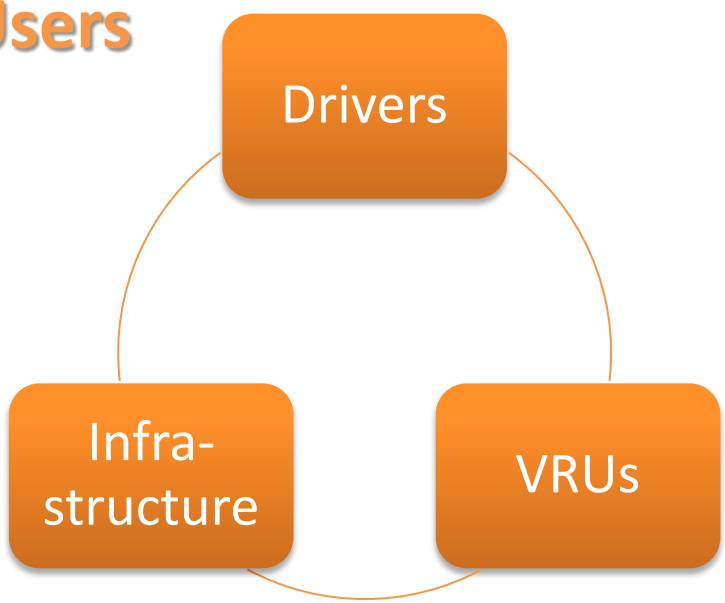
# Hybrid Communication in TIMON

## Technology

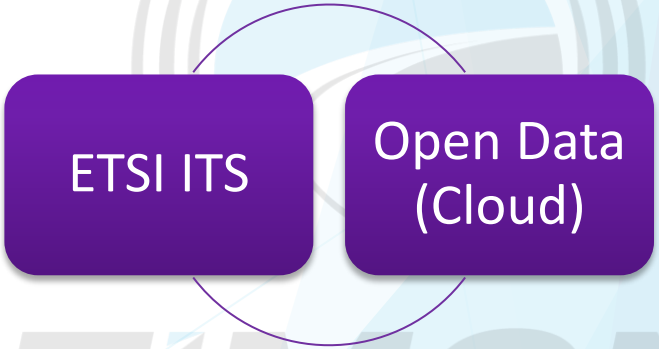

## Devices



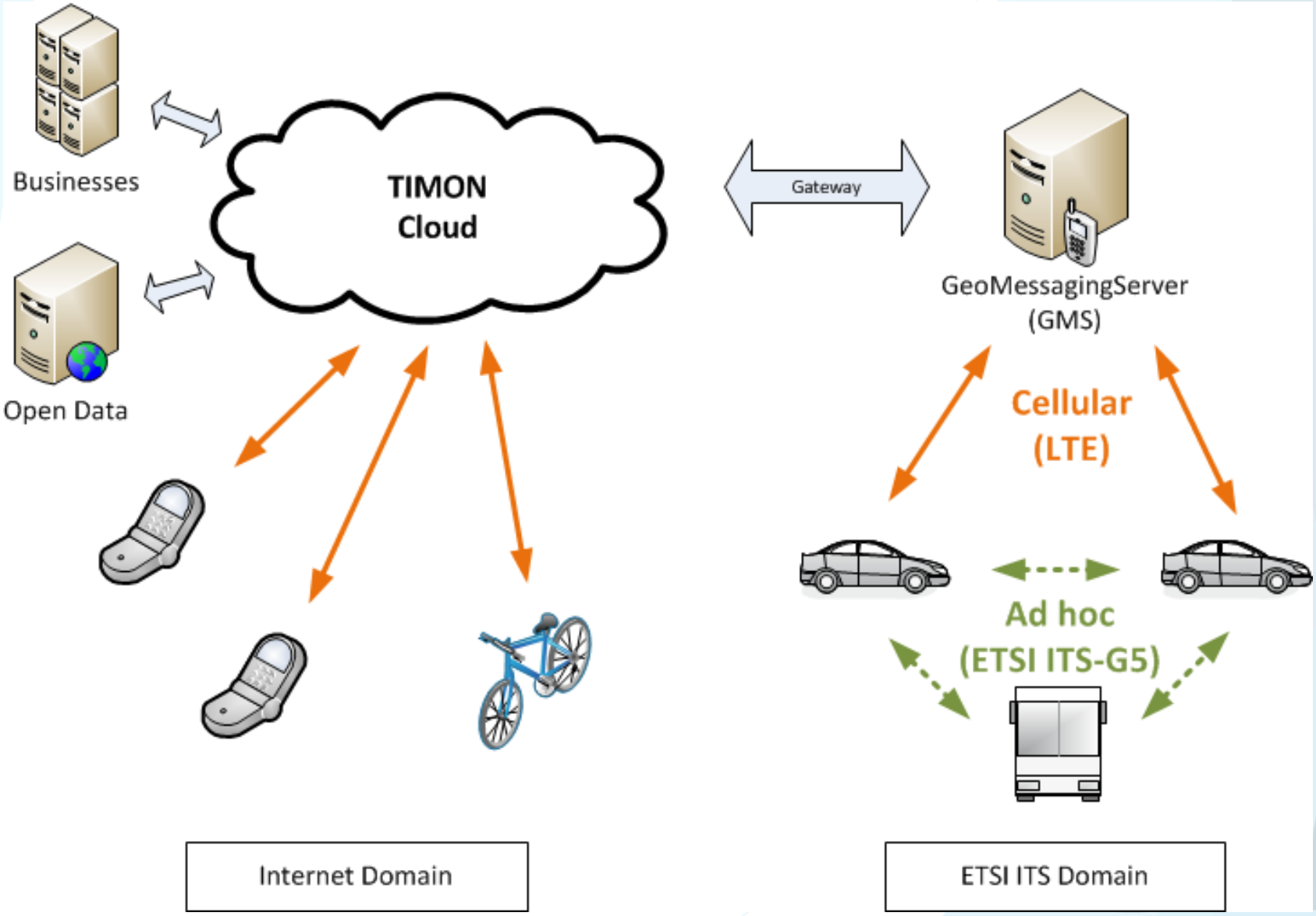

## Users




## Data Sources



# Communication Architecture



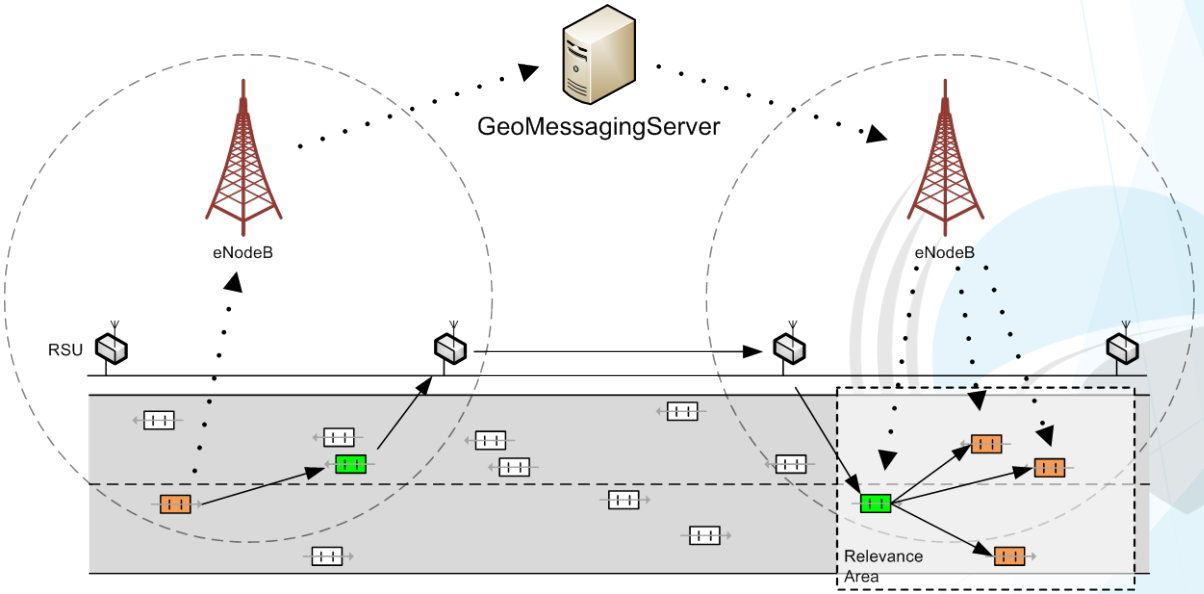
# Communication Domains

- **Internet**
  - Smartphone app for end-users, IP-based communication
  - Variable data formats, sources, protocols, patterns
    - In TIMON: aggregated and harmonized by TIMON Cloud
- **ETSI ITS (TR 101 607)**
  - Integrated devices in vehicles, public transport, road side units
  - ETSI ITS GeoNetworking / Basic Transport Protocol
  - Standardized Messages: CAM, DENM, SPAT, …
  - Time critical (safety) applications

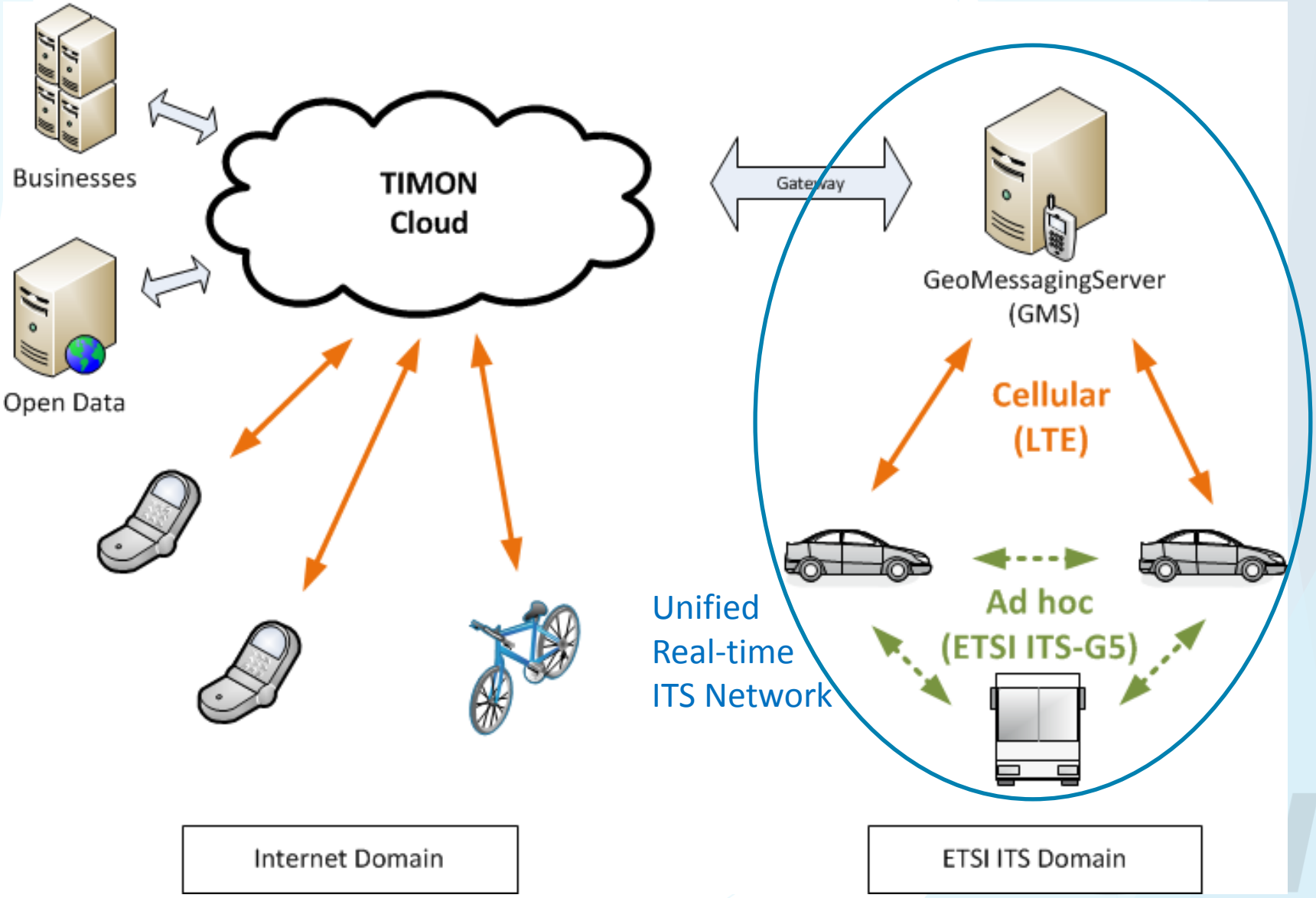
- **Gateway** mediates between the two domains
  - Cloud can trigger and receive warnings (DENM) and evaluate floating car data generated by CAMs

# Towards Hybrid ITS Networks

- Future ITS applications require **predictable** communication
  - Reliable, real-time communication
  - Feedback about available communication resources



# Communication Architecture Revisited



# Hybrid ITS Networks: Expectations

- Increased reliability
  - Redundancy creates additional dissemination paths
  - Combine the strengths of individual technologies
- Increased efficiency
  - Communicate with the most suitable technology
  - Direct local information exchange vs. cloud/fog/…
- QoS differentiation
  - Low-latency safety applications vs. best effort services
- Future-proof architecture
  - Consideration of multiple technologies from the start without reinventing applications and services every time
- Integration of new users and devices, e.g. VRUs

- Our approach: **Unified GeoNetworking** with **adaptive selection** of the optimal technology / network

# Network Selection Strategies in TIMON

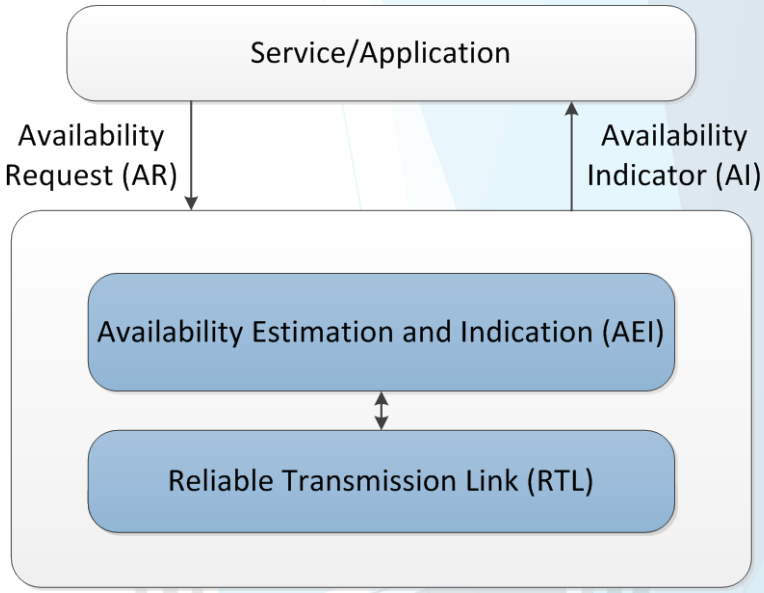
**If we have multiple communication channels (technologies) available, how do we select the right one?**

Reliability vs. Efficiency

- Policy-Based
  - Selection strategy specified *a priori* by experts
- **Availability Indication**
  - Online estimation of availability probabilities for each technology depending on requested QoS parameters
- Q-Learning
  - Online adaption of technology selection based on success/error feedback of previous attempts

# Availability Indication

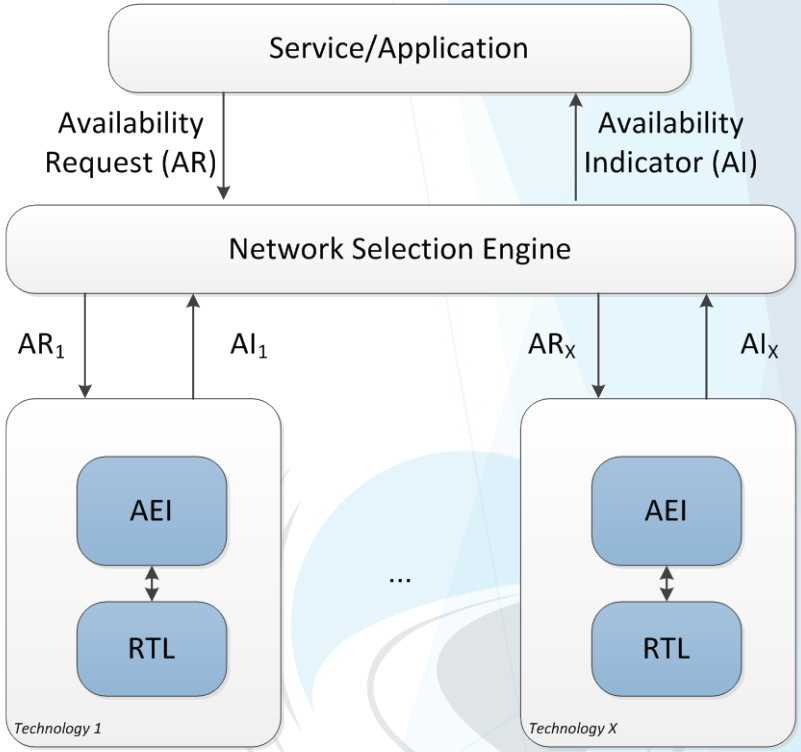
- **Availability Request (AR):** Minimum reliability threshold and/or maximum tolerable latency
- **Availability Indicator (AI):** Estimated probability of fulfilling the request
- Application can take action according to the indication




Schotten, Hans D., et al. "Availability indication as key enabler for ultra-reliable communication in 5G." 2014 European Conference on Networks and Communications (EuCNC), 2014

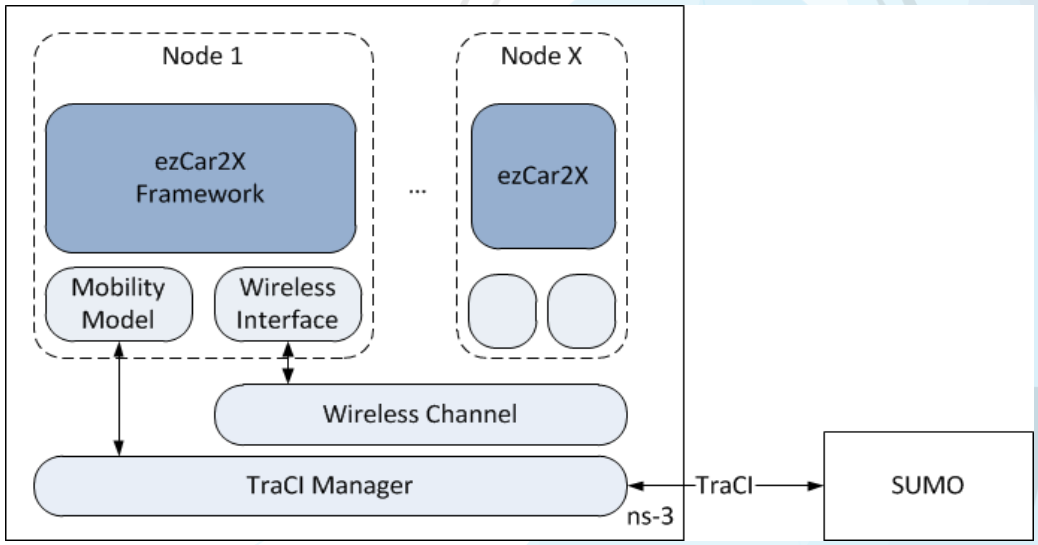
# Network Selection Using Availability Indication

- **Network Selection Engine:** Aggregates availability indication from multiple technologies
- Cost-based selection of one or multiple links to fulfill the request
- Independent estimators for each technology easily scale to new technologies



# Estimating Availability for ITS-G5

- Common communication patterns provide no feedback
- Estimation of link quality based on available information
  - Details will be published in *"K. Roscher, T. Nitsche, R. Knorr: Know Thy Neighbor - A Data-Driven Approach to Neighborhood Estimation in VANETs. In Proceedings of 2017 IEEE 86th Vehicular Technology Conference. Sep. 2017"*
- Data collection based on large scale simulation
  - Scenario: City of Luxembourg and surrounding highways
  - Environment:
    - ns-3
    - SUMO
    - Fraunhofer ESK's ezCar2X



# Estimating Availability for ITS-G5: Features

- Collected data
  - Local
    - Position, velocity, channel busy ratio, packet size, …
  - Remote information exchanged in beacons or CAMs
    - Position, velocity, beacon timing and signal strength, …
- Ranking of features according to mutual information with the transmission success (unicast and broadcast)
  - Most important: time since the last received beacon
  - Also significant:
    - Distance
    - Received signal strength
    - Difference between headings

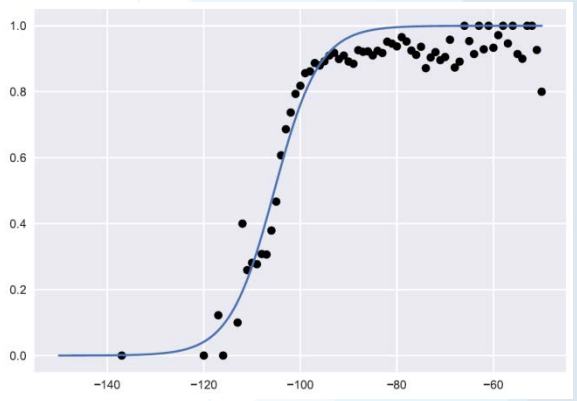
# Estimating Availability for ITS-G5: Results

- Estimation quality depends on communication mode and beacon frequency

- Unicast
  - Better predictable (retransmissions): up to 90% accuracy
  - Higher beacon frequencies improve accuracy
- Broadcast
  - Overall lower accuracy: 70% to 82%
  - Higher beacon frequencies decrease accuracy

# Ongoing Work

- Estimation of LTE availability based on RSRP
  - Good results in controlled simulation scenarios
  - Evaluation in high load situations
  - Investigation of additional parameters with suitable partners




- Performance of the selection algorithms is currently under investigation
  - Can be fine tuned towards efficiency or reliability
  - Opportunity to take application requirements into account
    1. Cooperative Awareness
    2. Cooperative Perception
    3. Cooperative Maneuvers
    4. …

# Summary

- ✓ Hybrid communication with an adaptive network layer enables transparent use of existing applications over a wide range of current and future technologies, e.g. ITS-G5, LTE/LTE-V2X, 5G, …
- ✓ Applications can efficiently leverage the benefits of all available communication channels without modification
- ✓ ETSI Network Layer security is technology independent
  - Pseudonym and authentication scheme can be used for other technologies as well
- × Standardization and technology availability
  - × ETSI GeoNetworking standard is currently tailored to ITS-G5
  - × Broadcast communication via cellular requires dedicated broadcast features (for scalability)

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# (a piece of the) Technological Challenge

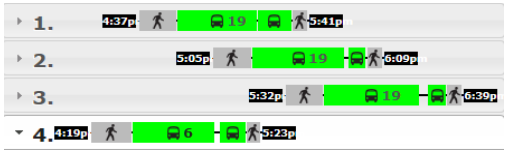
- Use of **data gathered thought communication** architectures for Development of advance Artificial Intelligence for:
  - Congestion Prediction
  - Intermodal Route Planning
- Use of **different sources** of data in a connected environment: vehicles, vulnerable road users, infrastructure and open data:
  - Vehicle as a **Sensor** → positioning, time stamp, speed…
  - Vulnerable road users as **Prosumers**: provide data and consume processed information
- Actual mobility services (mainly) based on infrastructure and open data
- Use of **real time** data

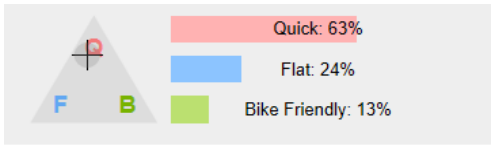
# Advanced Artificial Intelligence

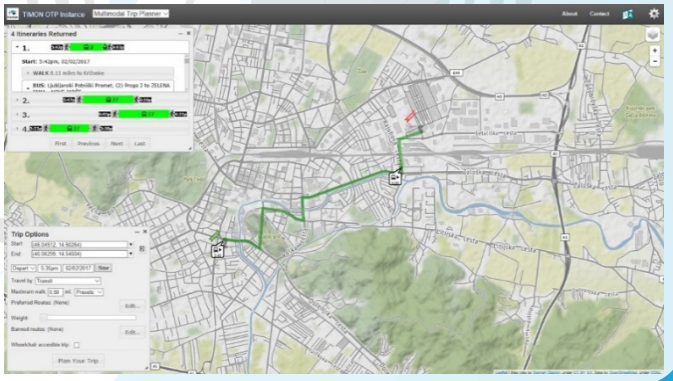
- **Interpretability**
  - Data Science in transport relies in classical AI
    - Decision Trees
    - Regression Techniques
    - Neural Networks
  - Focused on precision ←→ **Not interpretability**
- **Imbalance**
  - Traffic data is imbalanced: Abnormal situations are very rare
  - High accurate predictions ←→ **Not Useful**
    - No congestion at 4:30 am
    - No significant changes in traffic in next 10 minutes
    - Nobody in this room will win the lotto

# Proposed Approach

- Improved evolutive tuning of fuzzy based prediction models
  - Ordered multi-class problem (**Nearest state** predicted – better)
  - Cost-sensitive approach (**Uncommon state** hit – better)
  - **Class size** dependent accuracy
- Differential evolution based intermodal route optimization
  - $CO_2$ emission calculation (**Green routes**)
  - Triangle preferences (**Bike friendly**)
  - Public alternative route in high pollution days
  - Walking, bike, motorbike, vehicle, public transport (**Intermodal**)



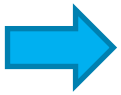



# Results

- 70% of data reduction
  - <10 minutes to build prediction models
  - <0.1 seconds to compute predictions
- 90% accuracy in predictions
  - 80% of hit for abnormal states
  - 99% of times error in road speed is less than 10km/h
- Models based in 4-15 rules using only about 5 variables

| Expected/Obtained | Normal | Increasing | Dense | Congestion |
|---|---|---|---|---|
| Normal | **0.96** | 0.043 | 0.00074 | 0.00010 |
| Increasing | 0.32 | **0.67** | 0.010 | 0.000059 |
| Dense | 0.098695 | 0.809953 | **0.091** | 0.00016 |
| Congestion | 0.31 | 0.65 | 0.033 | **0.0017** |



| Expected/Obtained | Normal | Increasing | Dense | Congestion |
|---|---|---|---|---|
| Normal | **0.88** | 0.12 | 0.0014 | 0.000024 |
| Increasing | 0.061 | **0.85** | 0.082 | 0.002 |
| Dense | 0.0093 | 0.16 | **0.80** | 0.019 |
| Congestion | 0.0012 | 0.056 | 0.15 | **0.79** |

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# TIMON Project

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**www.timon-project.eu**

*TIMON project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement no 636220.*

# Partners & Roles


- **11** organisations
- **8** countries
  - Spain, Germany, Italy, UK, Hungary, Slovenia, Belgium, Netherlands
- Project Coordinator – **DEUSTO**
- Technical Manager – **ISKRA**