EURECOM
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Simulations vs. Emulations for Evaluating Cooperative ITS Applications for Sustainable and Safe Mobility

Jérôme Härri - EURECOM

Workshop on Wireless Vehicular Communications
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Acknowledgments

- **This presentation and demos contains partial contributions from:**
  - Colleagues of the iTETRIS Consortium, in particular:
    - Daniel Krajzewicz, Laura Bieker, Matthias Roeckl (DLR), R. Blockpoel (Peek Traffic), Jeremie Leguay, Yoann Lopez (Thales), Javier Gozalvez, Ramon Bauza, Michele Rondinone, Miguel Sepulcre (UMH), Oscar Lazaro, Julen Maneros, Sendoa Vaz (CBT), Vineet Kumar (Hitachi), among others…
  - Colleagues of the OpenAir Interface @ EURECOM, in particular
    - Navid Nikaein, Raymond Knopp, among others…
- **Thanks to all of them for having provided contributions to this presentation !!**

Sustainable and Safe Mobility?

Sustainable and Safe Mobility??

- **Visionary Phase: GM Futurama**
  - Build a nation-wide transportation network
  - Car-to-Car communication for secured and fast mobility…
  - Yet: Capacity of Road Infrastructure grows slower than traffic

- **The safe and sustainable mobility conundrum:**
  - **Flow Theory**: $Flow = Density \cdot Speed$

Safety Authority: Drive Safe = Drive Slower

Transportation Authority: Sustainable Mobility = Roads used to their maximum capacity

Reduced Flow

Increased Density

Unsustainable Mobility

Unsafe Mobility

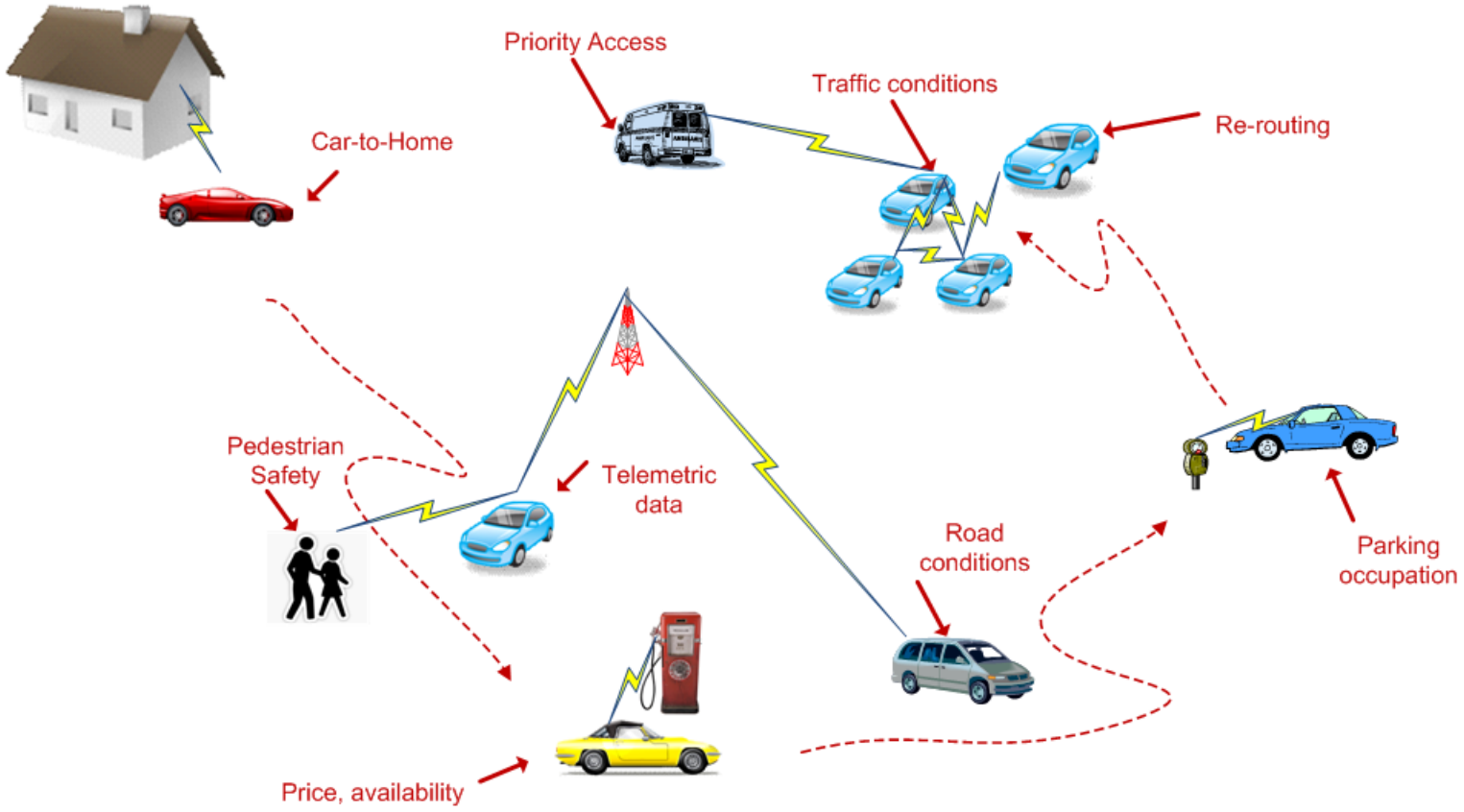
Sustainable and Safe Mobility??

- **The safe and sustainable mobility conundrum:**
  - **Flow Theory**: $Flow = Density \cdot Speed$

- **Directions?**
  - Increase Capacity of Road Infrastructure?
  - Reduce Flow?
  - Keep Speed?

- **ITS Applications**
  - Optimize the usage of road infrastructure
    - Cooperative navigation
    - Multimodal Transportation
  - Allows to drive fast and safe by forseeing danger

Intelligent Transportation Systems?



Objectives for Intelligent Transportation Systems

- **To avoid this…**

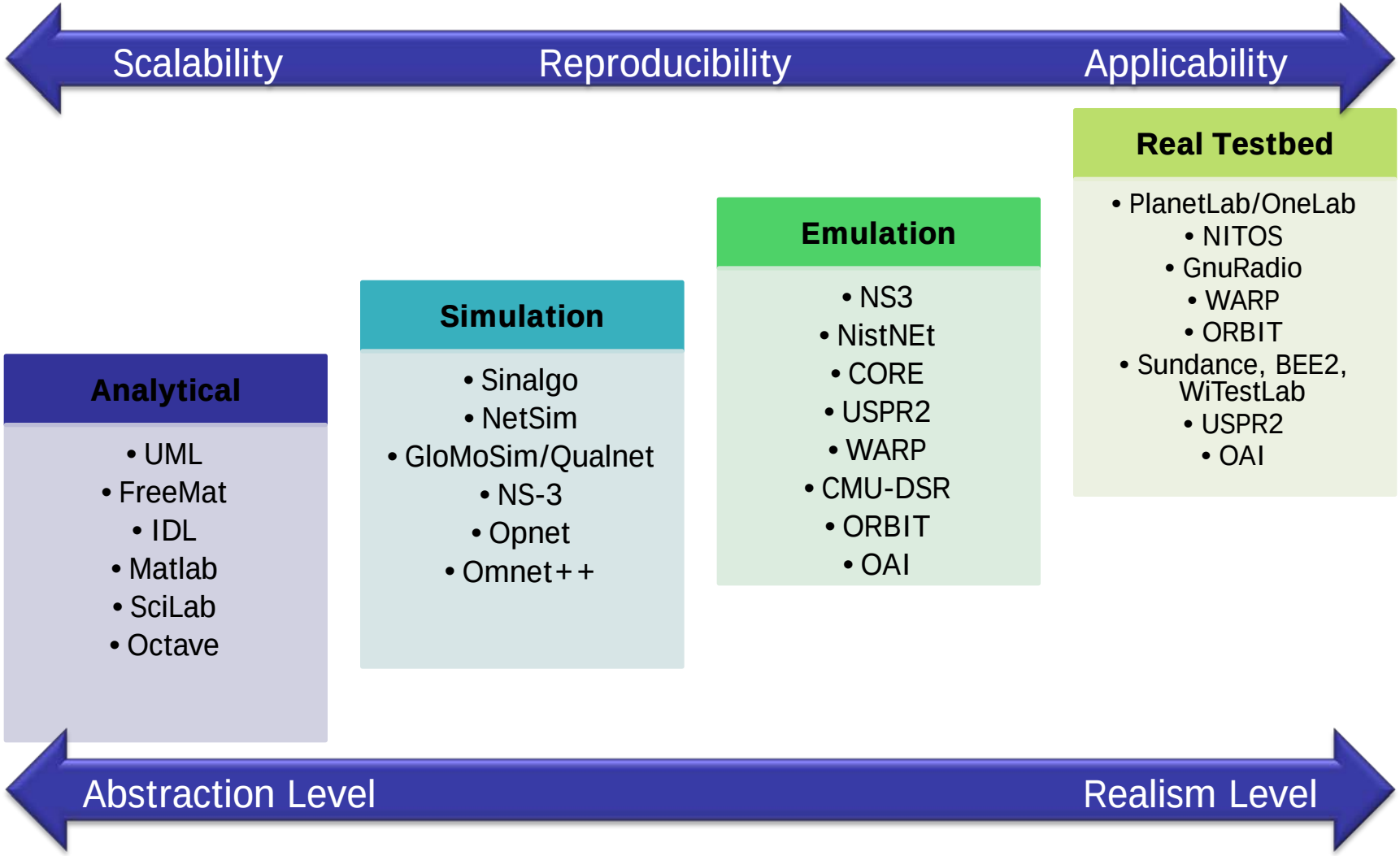
Evaluating ITS Applications

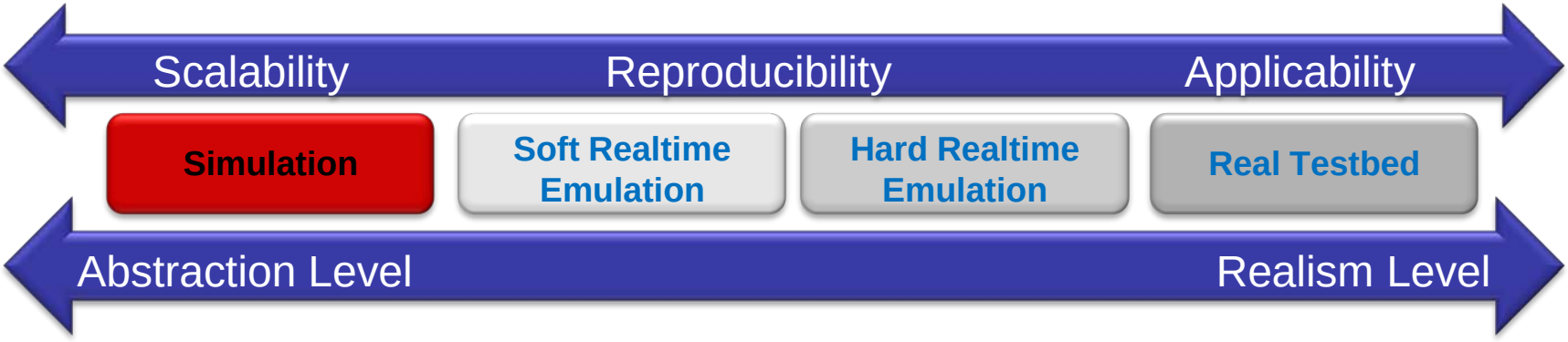
- **Optimally, through large field operational tests !**
- **Limitations:**
  - Safety:
    - cannot test when the safety of drivers or other vehicles are at risk
  - Scalability
    - Need to evaluate over a city-wide and over a long time period
  - Flexibility
    - Re-play
    - Modification
    - …
- **Simulations and Emulations are a natural option**
  - Simulators/Emulators are ‘just’ tools
  - Challenge:
    - Appropriate models
    - Close-to-Reality Scenarios
    - Flexible Methodology

A Brief Comparison

Experiment	Scenario Setup	Abstraction / Modeling	Reproducibility	Scalability / Costs	Limitation	Net Traffic & Mobility
Analytical	+	-	+++	+++	Complexity	Abstracted/ Modeled
Simulation	++	+++	+++	++	Abstraction	Modeled
Emulation	++	++	++	+	CPU/Cost	Modeled / Real
Real Testbed	+++	NA	-	-	Cost	Real

Classification of the Validation Platforms





ITETRIS OPEN SOURCE SIMULATION PLATFORM

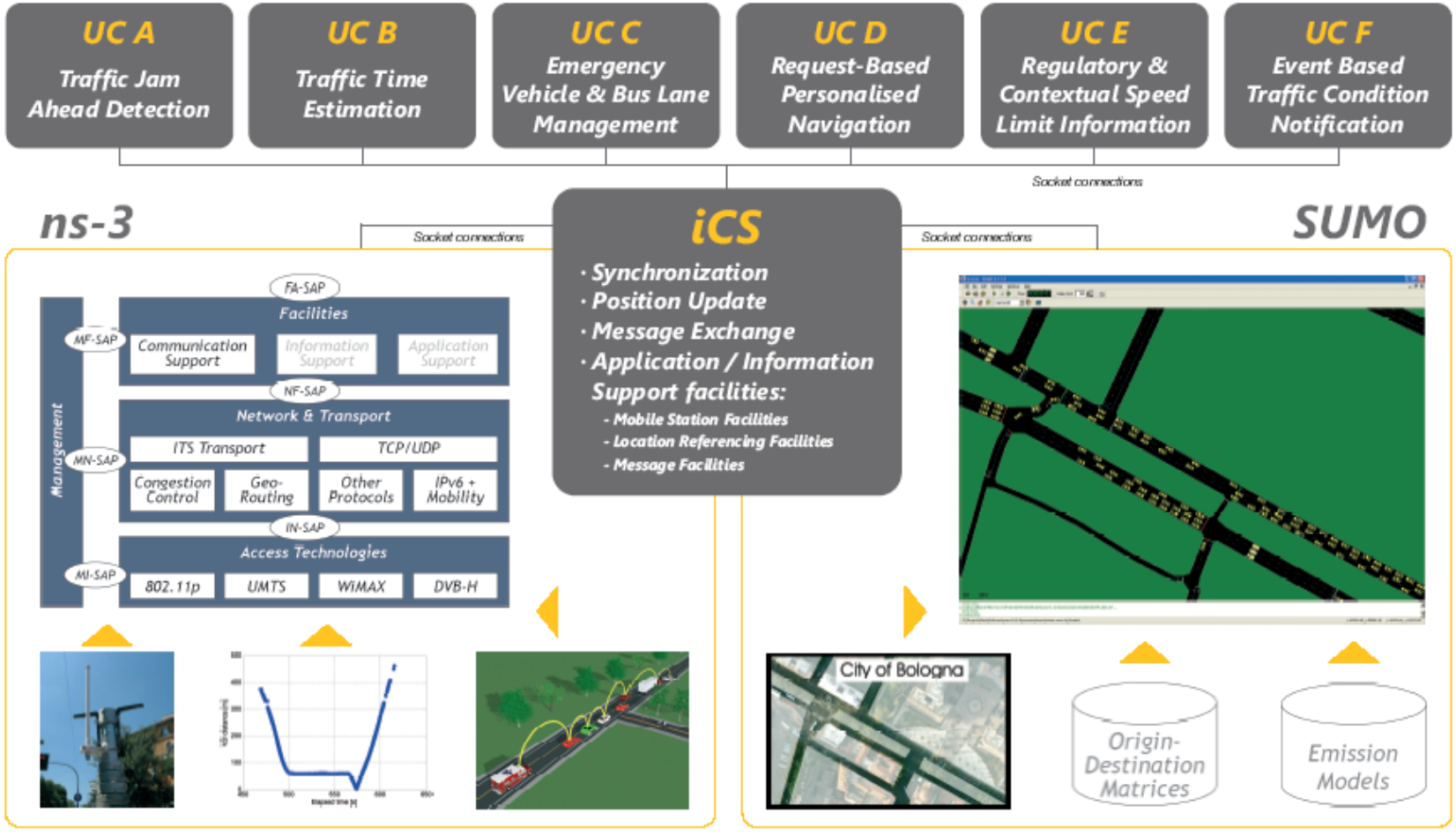
The iTETRIS Project

- **Main Objectives**
  - Build an integrated wireless and road traffic **simulation platform**
  - **For large-scale evaluation** of **cooperative** road traffic management solutions

- **Consortium and Acknowledgements:**

- **ICT-FP7 STREP project (Call 2)**
  - Strategic Objective: ICT for Cooperative systems
  - Website: http://www.ict-itetris.eu

The Open-Source iTETRIS Platform



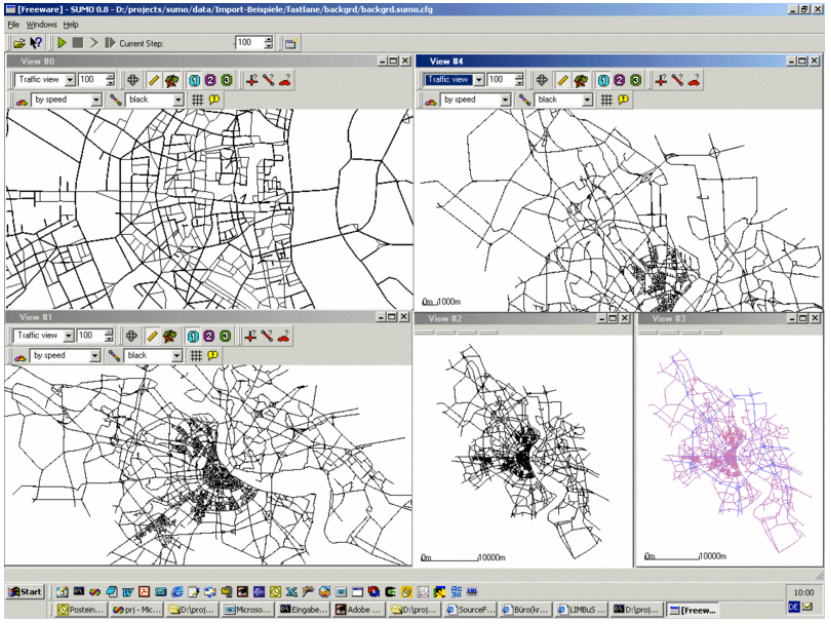
Source: M Roeckl, DLR, iTETRIS 2011

CHALLENGES FOR SIMULATING ITS APPLICATIONS

Challenge 1: Calibrated Traffic Scenarios

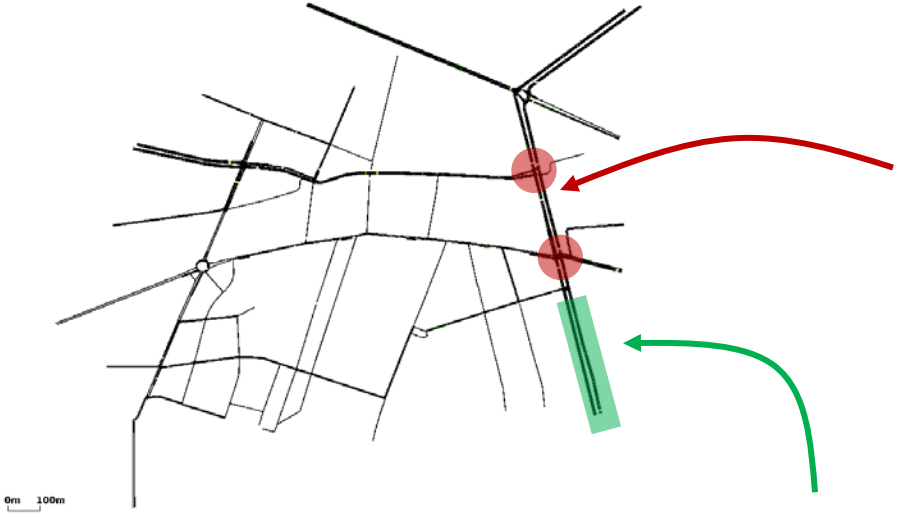
- **Simulation of Urban Mobility (SUMO)**
  - Open-source microscopic traffic simulator
  - Available: sumo.sourceforge.net

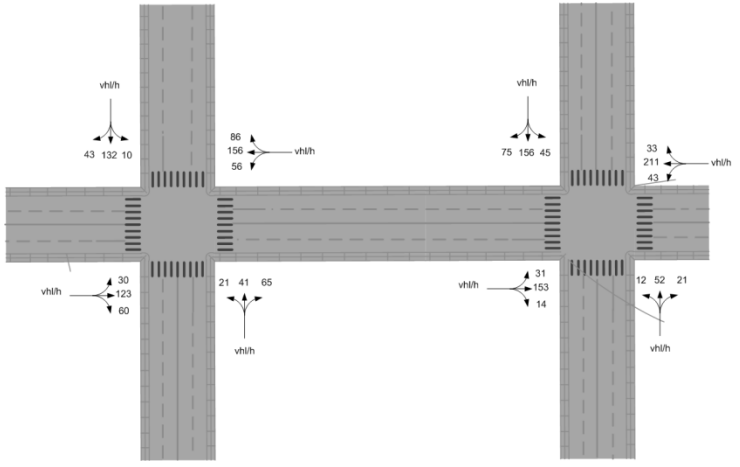
Function	Feature
Microscopic Model	Krauss Model
Macroscopic Model	O-D Matrix; weight-based shortest path
Extensibility	online APIs for route change, traffic lights, infrastructure retrieval, interactions with vehicles
Traffic Light Control	Embedded and through APIs
iTETRIS-specific Features	
Scenarios (Bologna)	Validated Urban (Pasubio-Costa); Suburban (Irnerio); Highway
Emission Model	HBEFA [10]
Noise Model	HARMONOISE [15]



Calibrating Scenarios: Bologna

- **Calibrating Traffic Scenarios in SUMO**
  - Digital Map (up to the lane level)
  - **Traffic Volumes** on Road Segments
  - **Turning Ratio** at intersections





Coordinates: 120608 Location: 1100 BURRARD ST

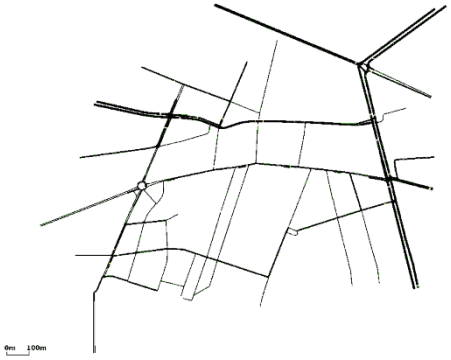
DIRECTION: NB

ID	Date	Hour	12-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	24 Hours	9AM-4PM	7-9AM	4-6PM
26771	Apr-25, 06	A.M.	-	-	-	-	-	-	-	-	-				16065	6272	2539	1822
		P.M.	-	862	824	829	897	925	838	773	723	644	603	366				
26772	Apr-26, 06	A.M.	229	167	136	75	89	179	610	1264	1275	1129	890	867	-	-	-	-
		P.M.	871	-	-	-	-	-	-	-	-	-	-	-				

DIRECTION: SB

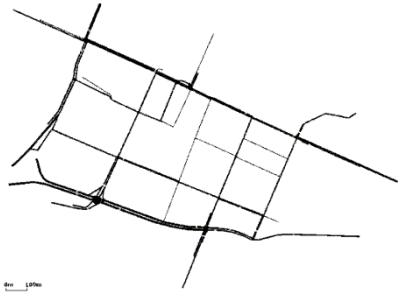
ID	Date	Hour	12-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	24 Hours	9AM-4PM	7-9AM	4-6PM
26773	Apr-25, 06	A.M.	-	-	-	-	-	-	-	-	-				15072	6087	1300	2523
		P.M.	-	833	1022	1035	1199	1324	1071	800	618	640	551	338				
26774	Apr-26, 06	A.M.	232	129	125	70	61	102	425	587	713	727	733	838	-	-	-	-
		P.M.	899	-	-	-	-	-	-	-	-	-	-	-				

Calibrated Scenarios in iTETRIS

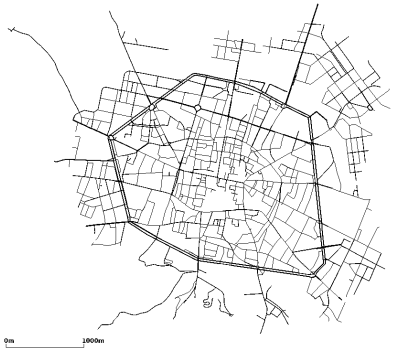


acosta
179 nodes, 182 edges
8888 vehicles in total
~550 vehicles max.

irnerio
410 nodes, 749 edges
10367 vehicles in total
~900 vehicles max.



pasubio
135 nodes, 111 edges
8681 vehicles in total
~1400 vehicles max.



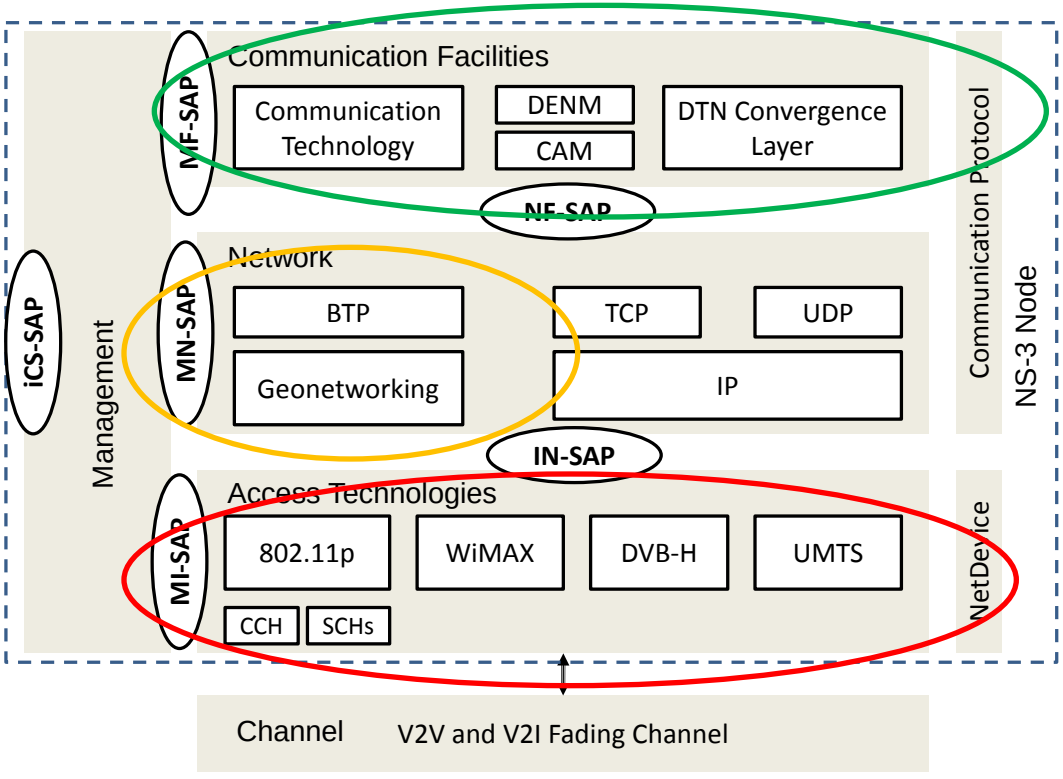
ringway
1210 nodes, 2216 edges
19987 vehicles in total
~2000 vehicles max.

joined
309 nodes, 271 edges
11079 vehicles in total
~950 vehicles max.

highway
1140 nodes, 2157 edges
46026 vehicles in total
~2500 vehicles max.

Challenge 2: Vehicular-specific Heterogeneous Communication Simulator

- **Network Simulator: ns-3**
  - http://www.nsnam.org/
- **Good general network simulator**
  - Not adapted to vehicular-specific communication and protocols
  - Added the ETSI ITS protocol stack



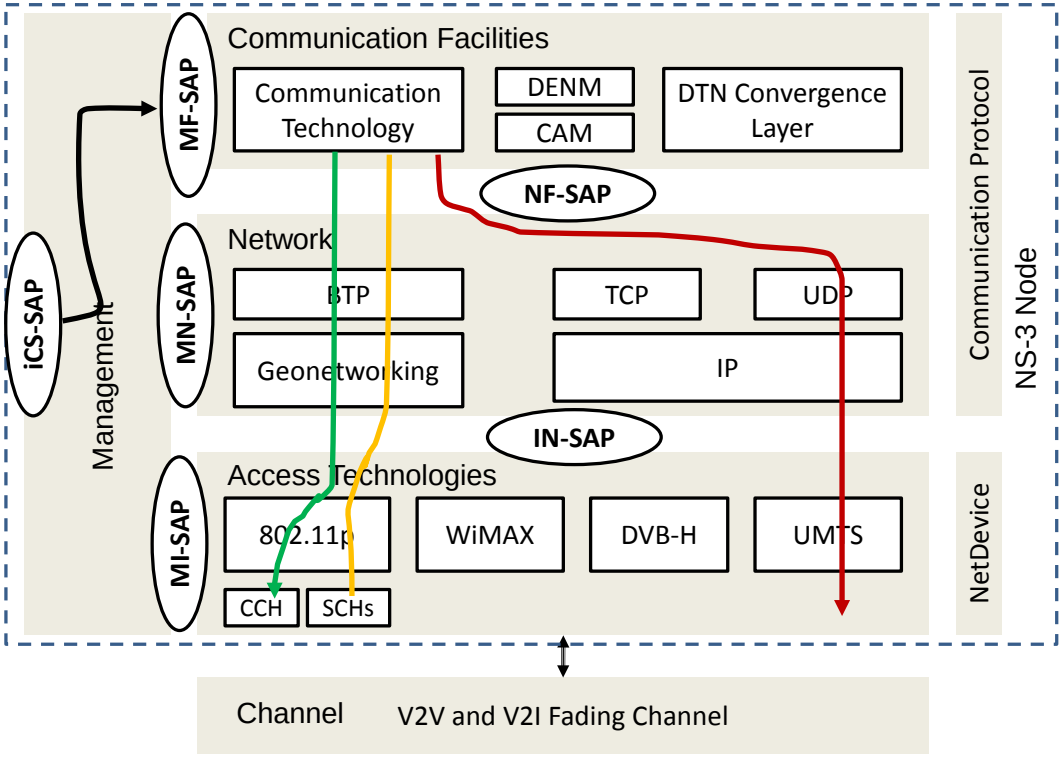
Intelligence in the Communication Stack

Position-based Geographic Routing

Heterogeneous Access Technologies

Optimal Communication Technology Selection

- **Network Simulator: ns-3**
  - http://www.nsnam.org/
- **Good general network simulator**
  - Not adapted to vehicular-specific communication and protocols
  - Added the ETSI ITS protocol stack



Traffic Safety - Beaconing

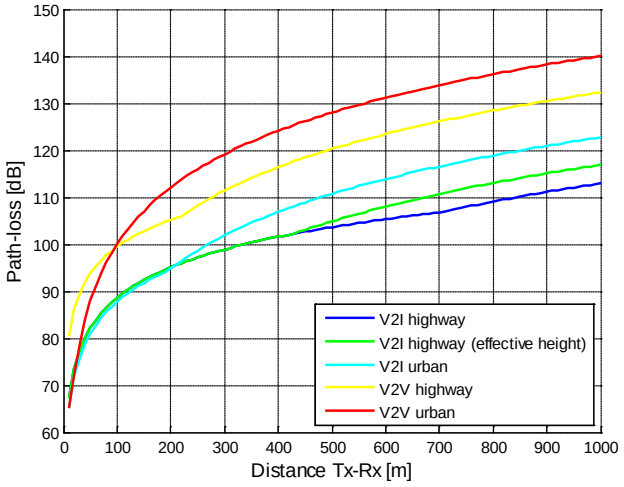
Traffic Efficiency – Traffic Light Info

Traffic Management – Traffic Information

Vehicular Channel Models

ITSG5A / 802.11p / DSRC

	Urban	Highway
V2V	WINNER B1 - Urban microcell	Cheng & Stancil
V2I	WINNER B1 - Urban microcell	WINNER D1 - Rural



Cellular

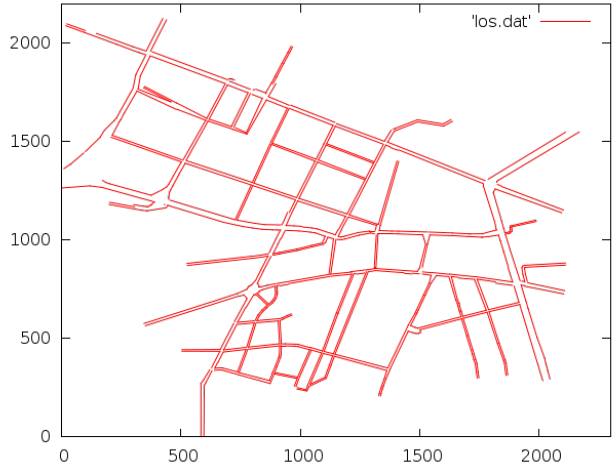
	Urban	Highway
WiMAX	WINNER C2	WINNER D1
UMTS	WINNER C2	WINNER D1
DVB-H	Okumura-Hata Urban and Suburban	Okumura-Hata Rural

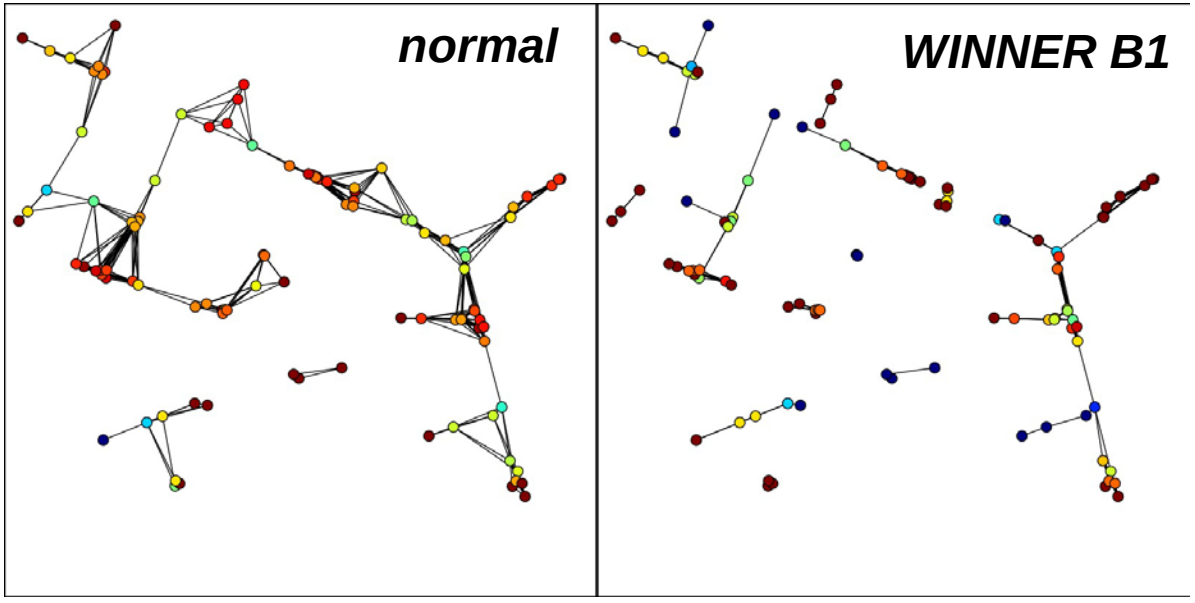
- **WiNNER C2 - Urban macro-cell (2-6 GHz)**
- **WiNNER D1 - Rural macro-cell (2-6 GHz)**
- **Okumura-Hata - Macro-cells (100 - 1500 Mhz)**

Source: J. Gozalvez, R. Bauza, M. Rondinone, M. Sepulcre, UMH, iTETRIS 2011

Impact of the iTETRIS Fading Models on Network Connectivity

- **Close-to-Reality Fading Models**
  - Effects of non-LOS in urban settings
  - WINNER B1 model for WAVE propagation

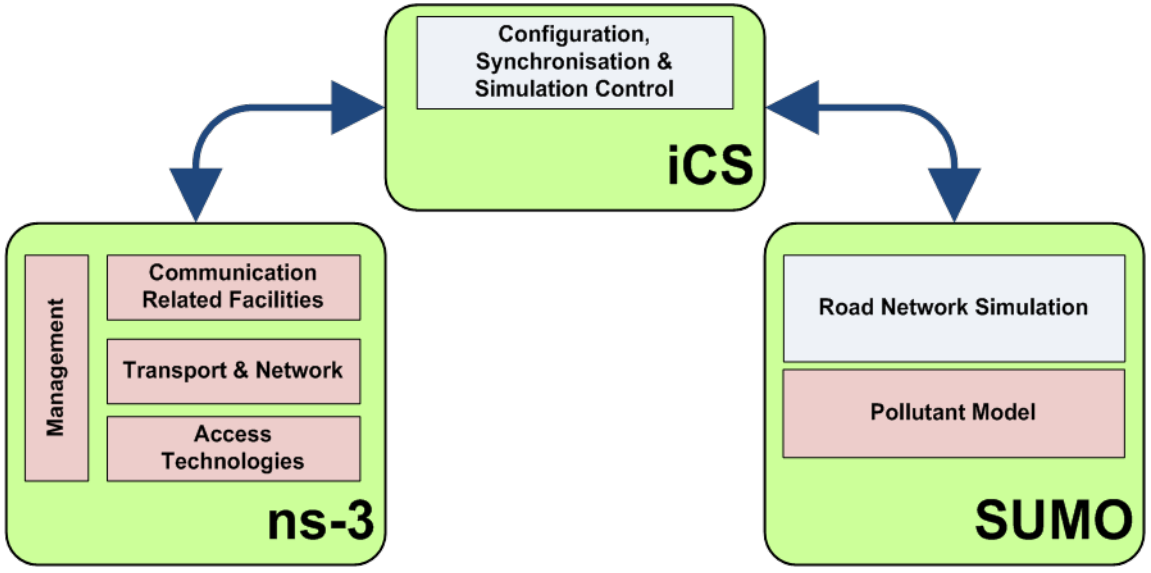




Source: Y. Lopez and J. Leguay, Thales, iTETRIS 2011

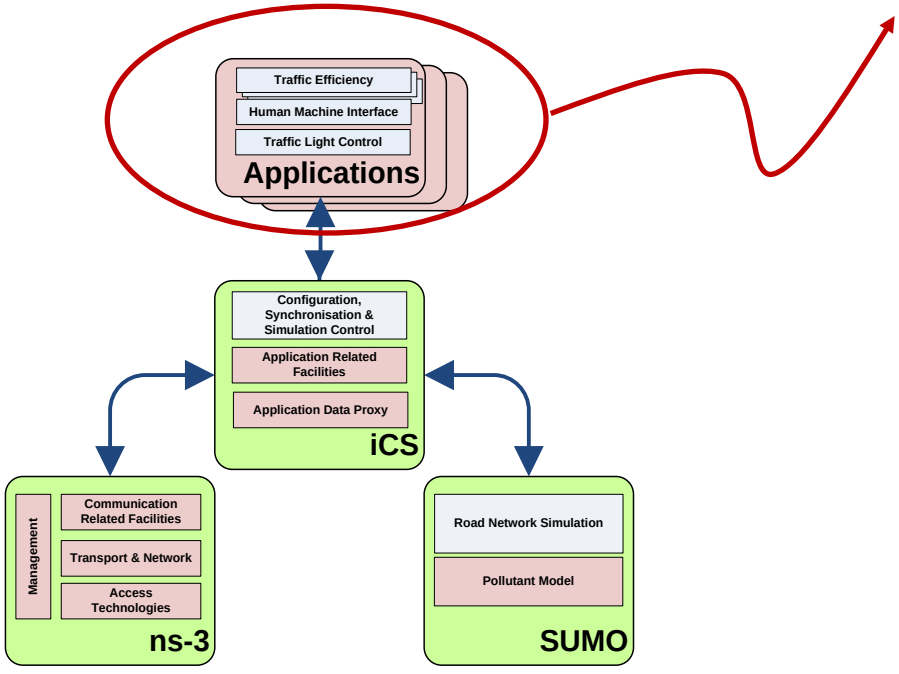
Challenge 3: Bi-directional Interaction

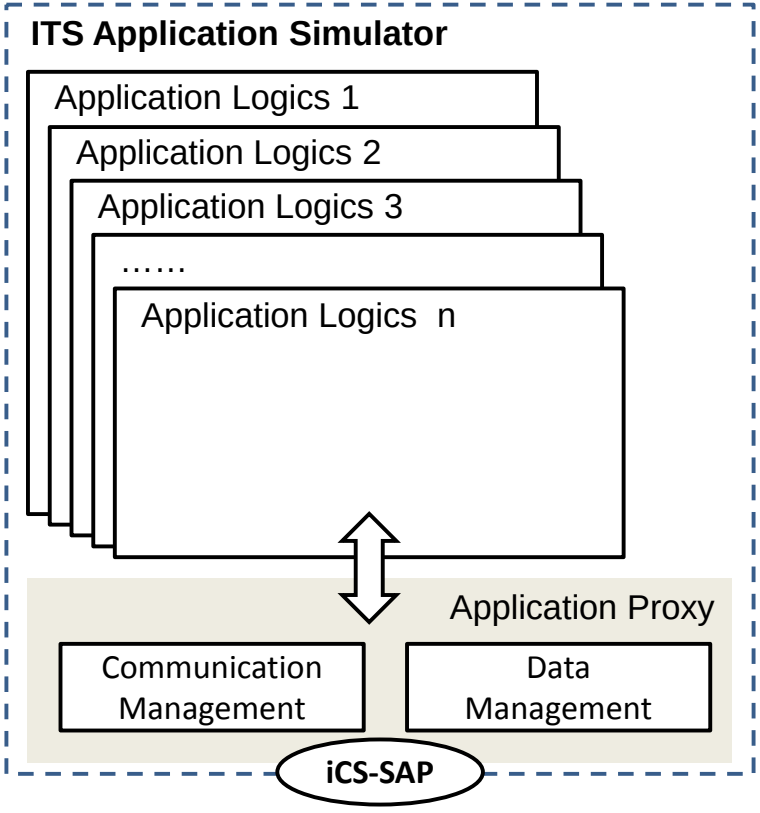
- **Fundamental Difference between ITS and standard wireless networks**
  - Mobility is not a perturbation
  - Mobility IS the application
    - We need to model it
    - We need to **control** it



Challenge 4: Modeling and Integrating ITS Application

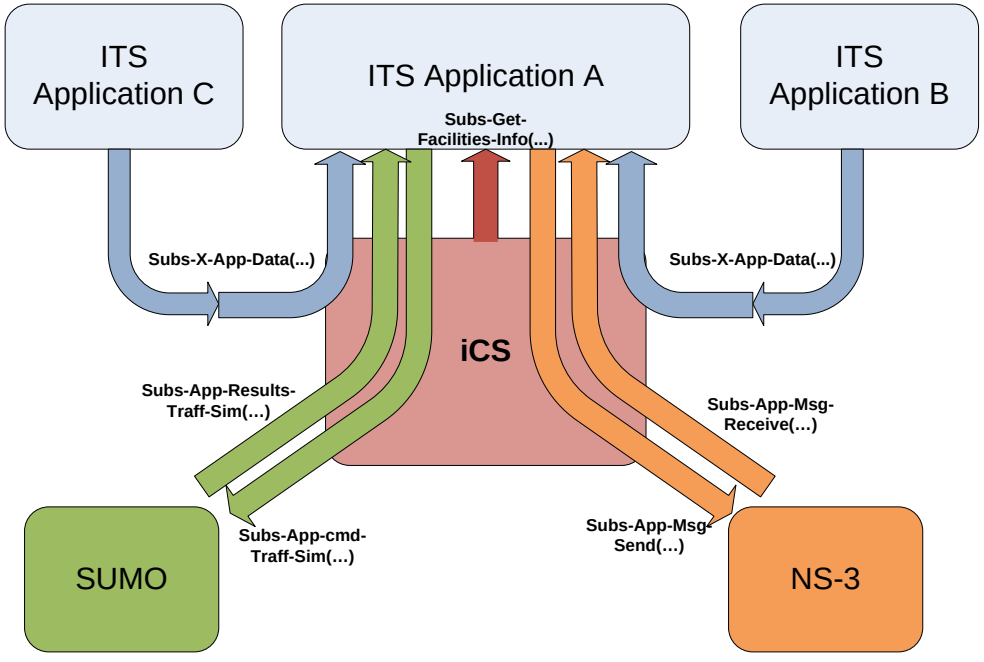
- **Applications are independent entities**
  - Modeled as third module
- **Application Simulator:**
  - Lightweight module
  - Open APIs
  - Provided for C++, Python and Java





Challenge 5: Interaction between ITS Applications and other Modules

- **Subscription are used to send or retrieve data to modules**
  - Portability and extensibility are required
- **Developed six generic open APIs**
  - TLV (Type-Length-Value) Encoding



SUMO:
Push(Data): re-route…
Pull(Data): getSpeed,…

NS-3:
Push(Data): send-broadcast,..
Pull(Data): getStatistics, receiveMsg..

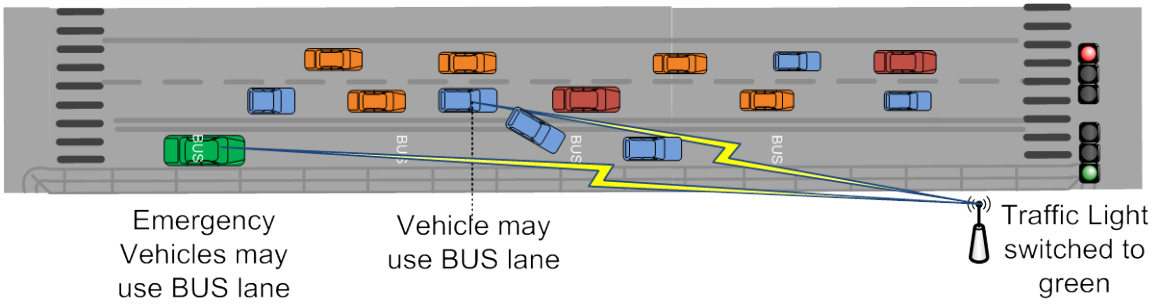
iCS
Pull(Data): getPosition, getNeighbors

Application
Pull(Data): application-results
Push(Data): application-results

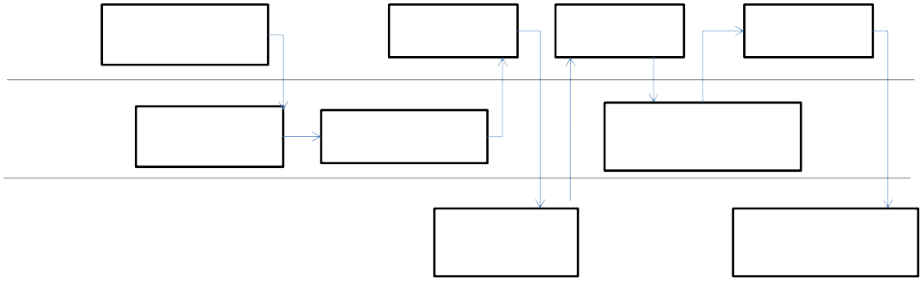
SOME APPLICATION RESULTS

Smart Bus Lane Usage for Emergency Vehicles

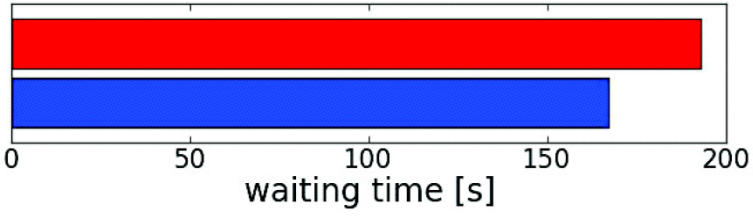
- **Scenario**
  - Pasubio



- **Application Flows**



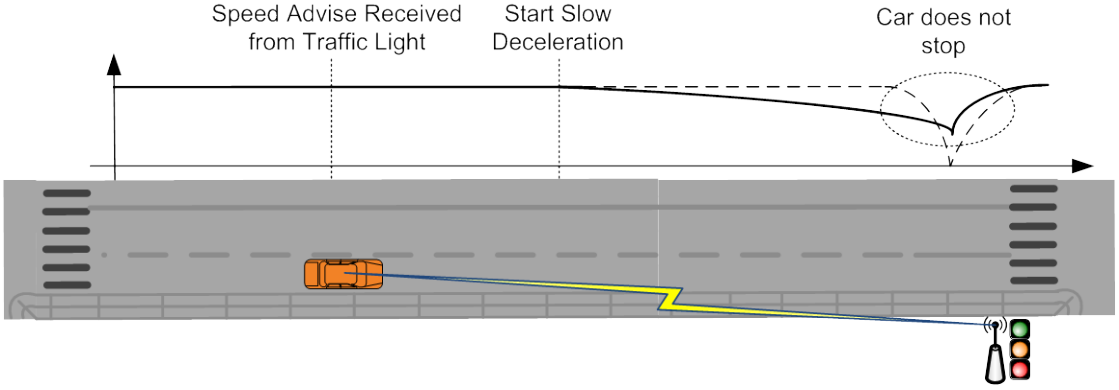
- **Results (average)**



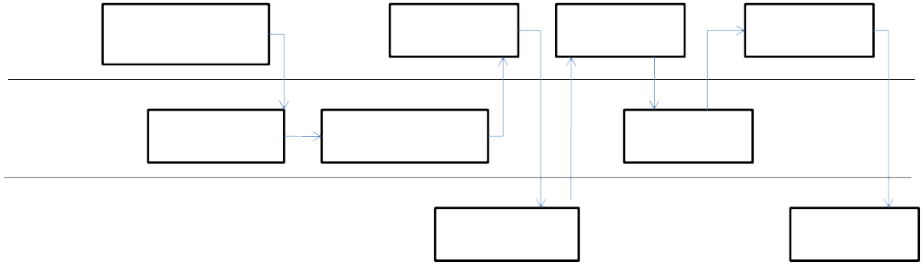
Source: D. Krajzewicz, L. Bieker, DLR, iTETRIS 2011

Optimized Speed Advisory Application

- **Scenario**
  - Pasubio



- **Application Flows**

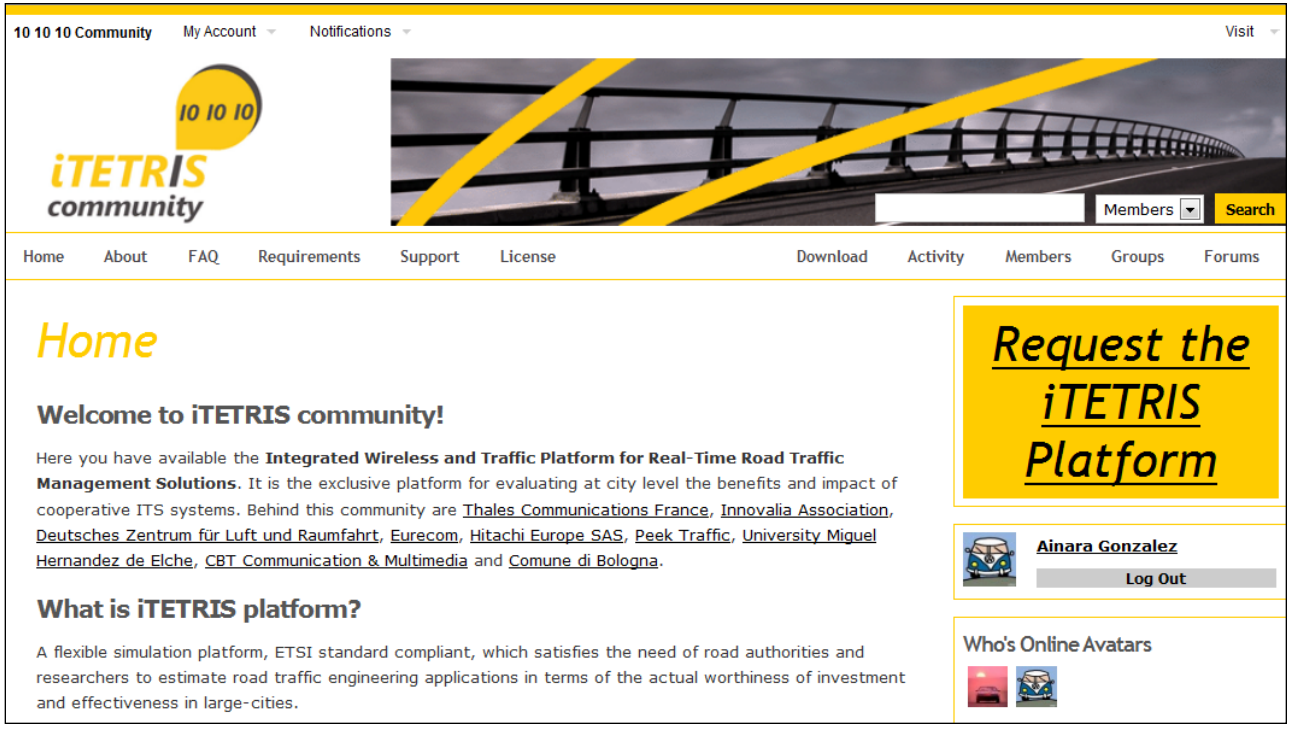


- **Results (average)**

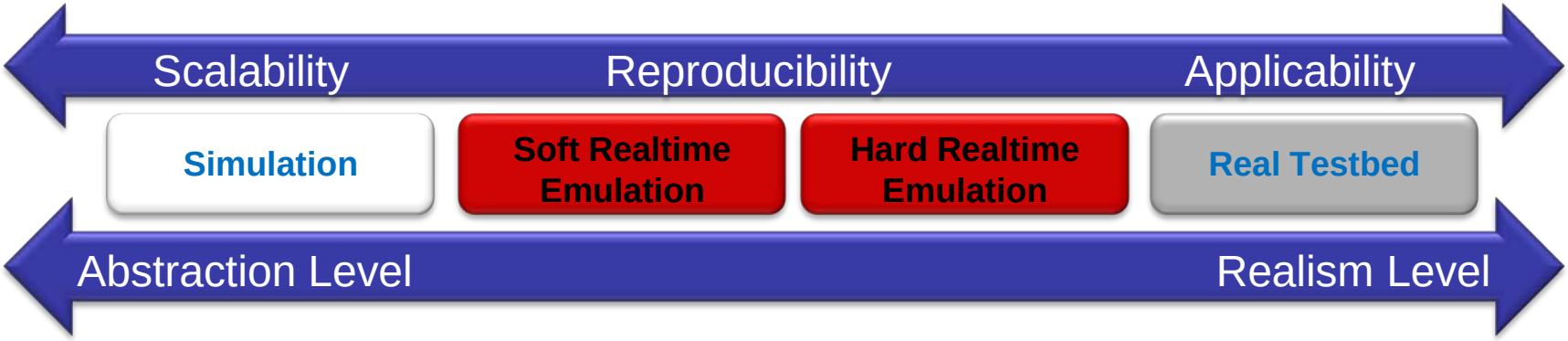
Speed Limits (Km/h)	50	50	50	70	70
Distance (m)	none	500	1000	500	1000
CO2 reduction	**0%**	**13.67%**	**24.84%**	**22.21%**	**28.31%**

Source: R. Blokoel, Peek Traffic, iTETRIS 2011

Join the iTETRIS Community !!

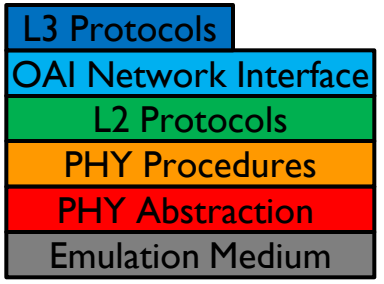


www.ict-itetris.eu/10-10-10-community



OPENAIR INTERFACE EMULATOR

Building Blocks



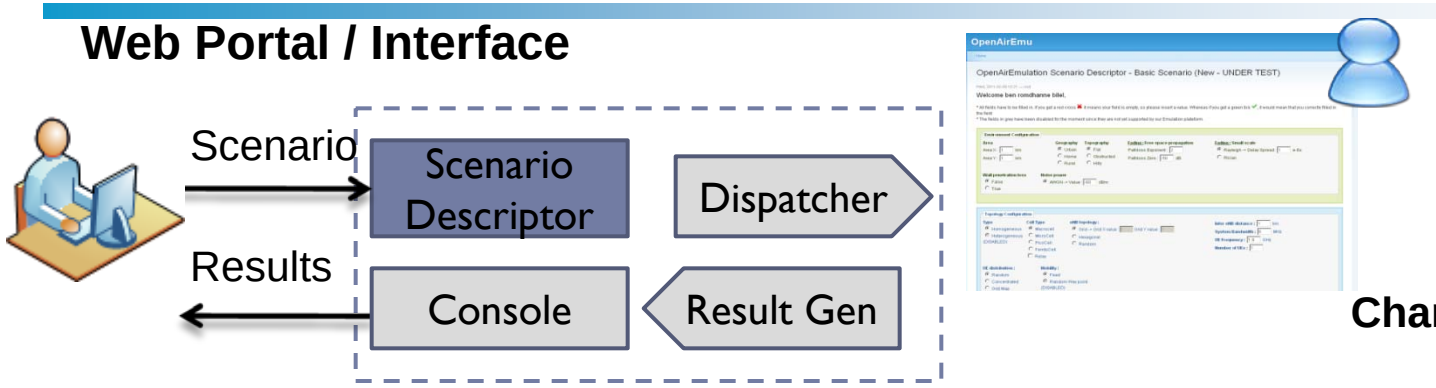
- **Linux IP network interface**
- **Real L1/L2/L3 protocol stack (not modeled)**
- **PHY Abstraction**
  - Modem, physical channels, along with propagation
- **Emu transport mechanism (or combination)**
  - Direct memory transfer for realtime behavior with virtualized protocol stack
  - Ethernet (ip multicast) not realtime
    - ECOS and RTNET support realtime Ethernet
- **A set of tools**
  - Mobility, traffic, channel models

Architectural Design

- **Scalability of the experiment**
  - Protocol virtualization and parallelism
  - Optimized emulated data transport
  - Offloading capabilities depending on Hardware
- **Applicability of the experiment**
  - Real protocol stack (not modeled) interconnected with Linux TCP/IP network stack
  - Hard realtime and soft realtime operations (RTAI)
  - Attach real applications (emulate the remaining traffic)
  - Feed real channel traces
  - Interconnection with a live network

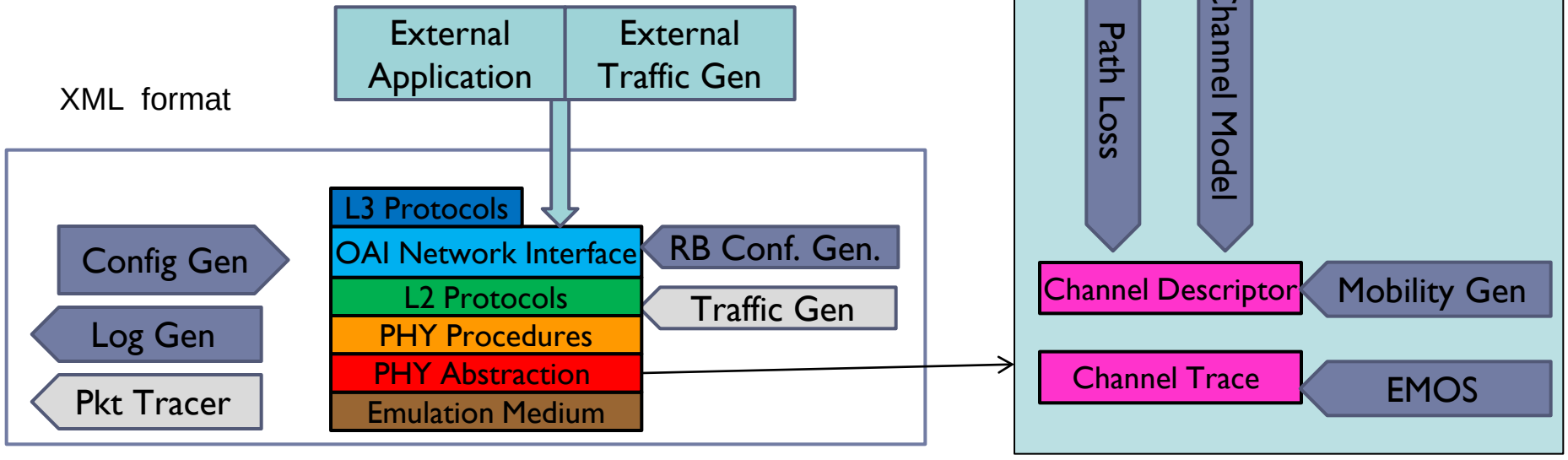
Experiment Design

Web Portal / Interface



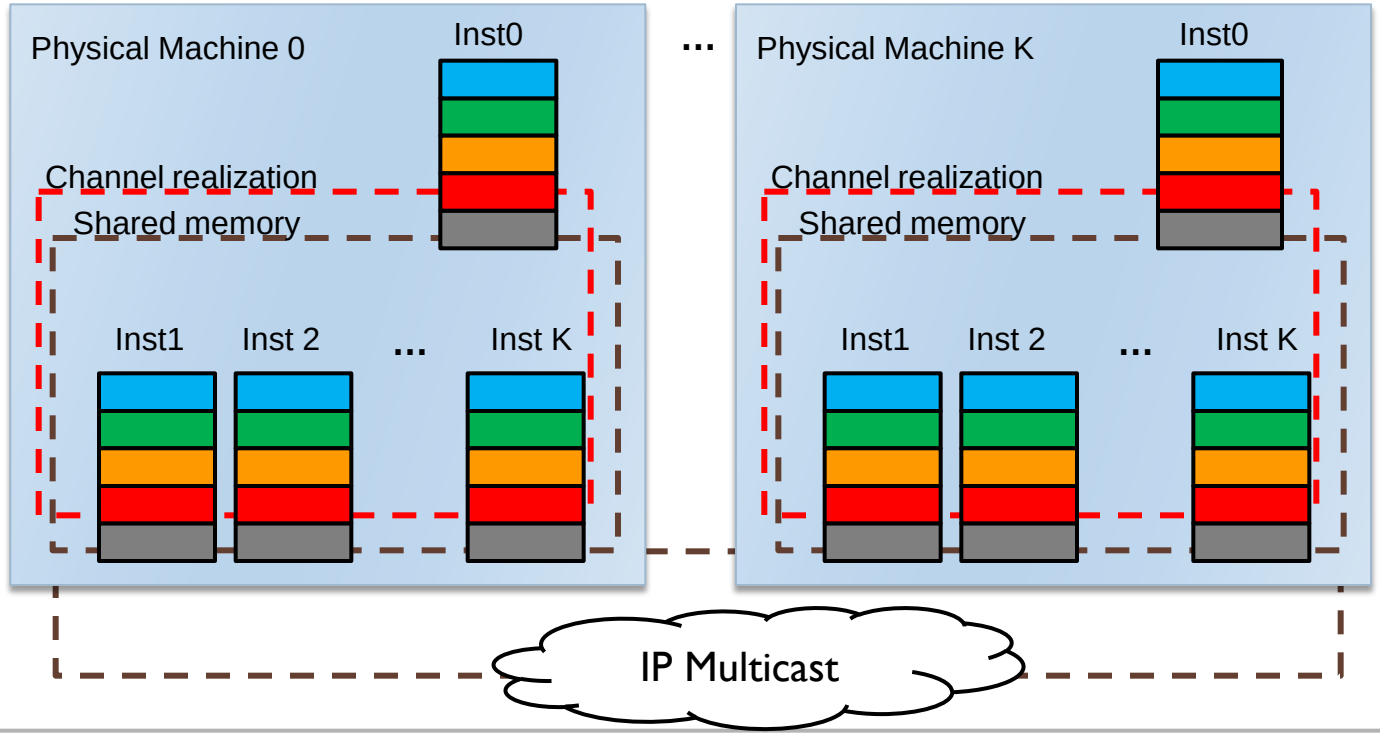
Channel Realization
NB2UE
UE2ENB

OAISIM - OAIEMU



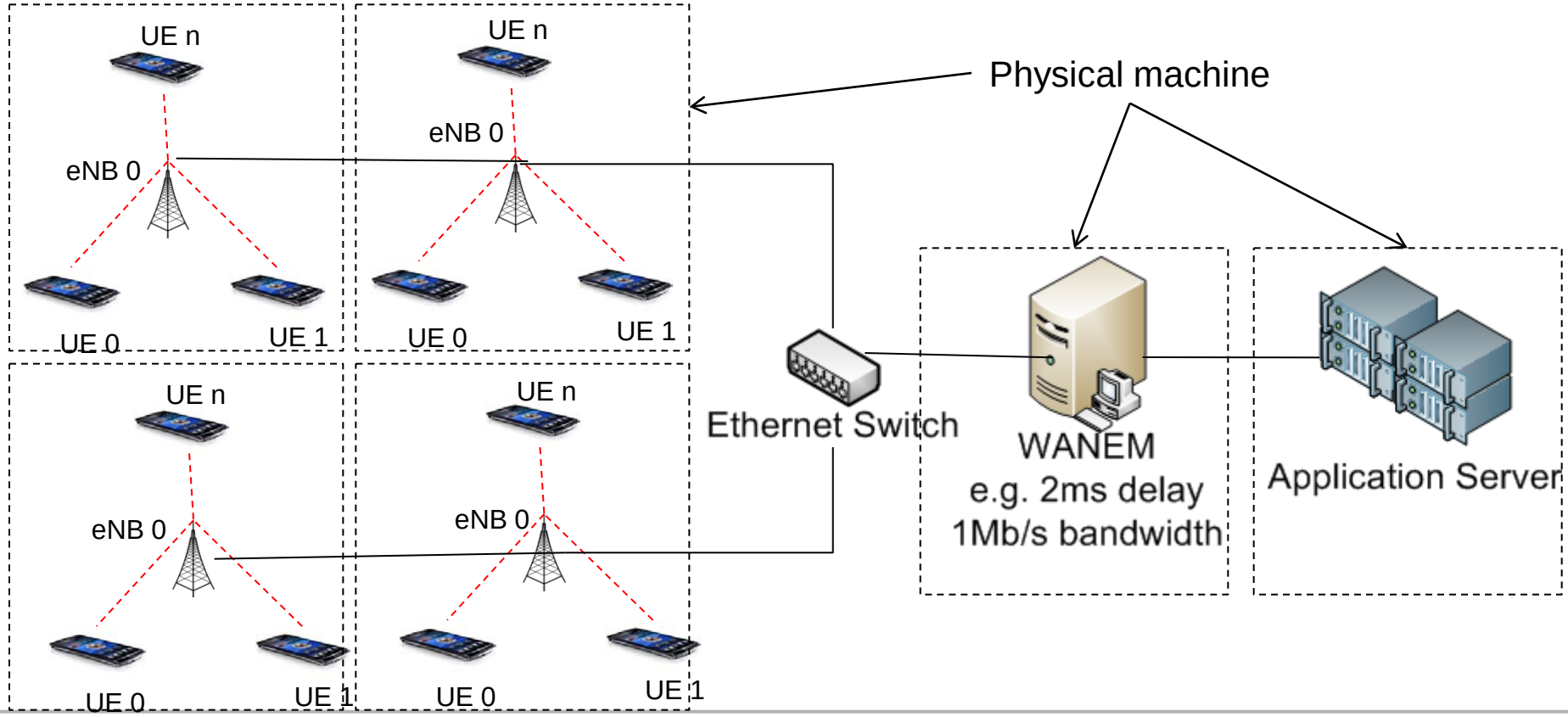
Emulated Medium

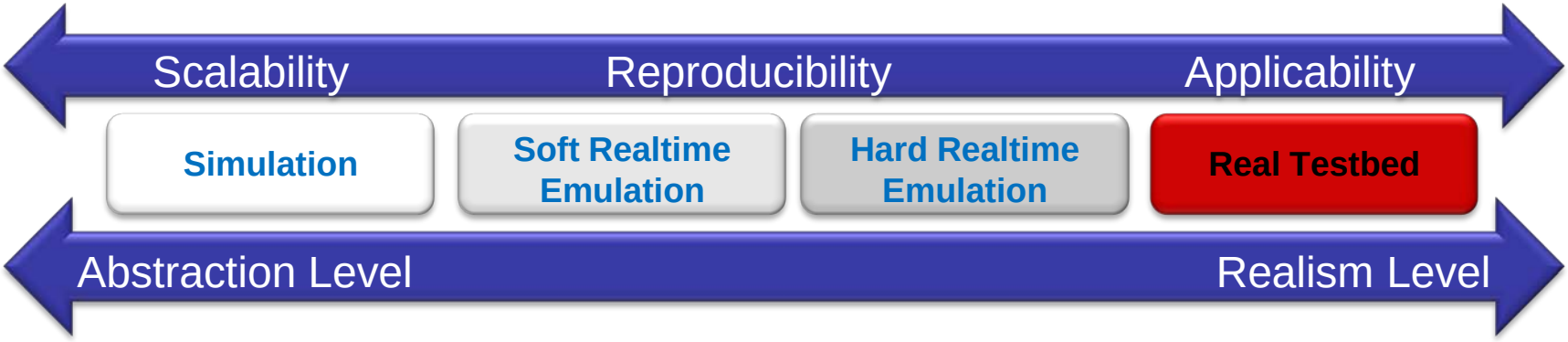
- **Emulated data are exchanged through two techniques**
  - Shared memory
  - IP multicast over Ethernet (or any other medium)



Use case : Smart City (LOLA Testbed)

- City/hot zone in the area of 2000x2000
- 4 static dense small cells in grid of 2x2 (pico cell) and 60 UEs randomly distributed with mixed mobility
- Mixed human and machine traffics based on WP3 models

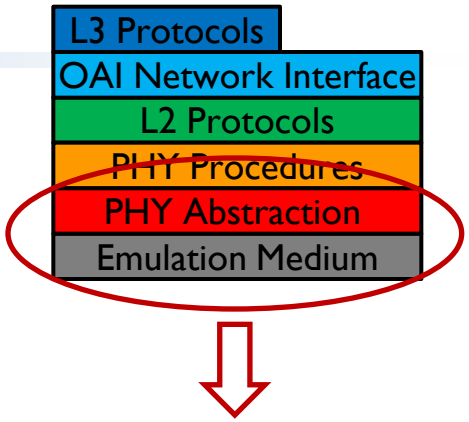




OPENAIR INTERFACE

Test Bed Building Blocks

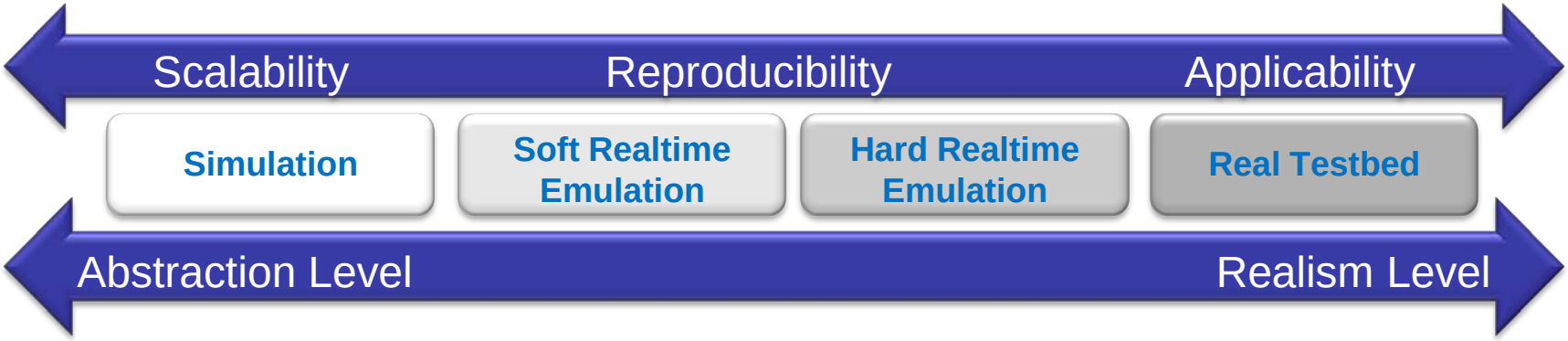
- **Experimental Licenses from ARCEP (French Regulator) for medium-power outdoor network deployments**
  - 1.9 GHz TDD, 5 MHz channel bandwidth
  - 2.6 GHz FDD (two channels), 20 MHz channel bandwidth
  - 800 MHz FDD (two channels) : 10 MHz channel bandwidth
- **IDROMEL reconfigurable radio architectures**
  - Agile RF and ExpressMIMO fully reconfigurable RF and baseband DSP
  - Heterogeneity in networking protocols
  - Full SDR description of air interfaces
- **Air interface applications**
  - LTE / LTE-A
  - DAB
  - IEEE 802.11p PHY
- **Real-time Two-way and Multiuser Channel sounding**



GNU GPL License

Summary - Thank you for your Attention !!

- **Each Methodology is adapted to specific requirements**



- **Join the Communities:**
- **iTETRIS: *www.ict-itetris.eu/10-10-10-community***
- **OpenAir Interface: www.openairinterface.org**
- **OpenAir Interface EMU: emu.openairinterface.org**
- **More Information:**

its@eurecom.fr

Jerome.Haerri@eurecom.fr