Including citizens in the design of Smart Cities: Needs and results

Challenges of interdisciplinarity

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Urbanet team, Inria - Insa Lyon

ICT makes cities smart

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ICT makes cities ~~smart~~ smarter

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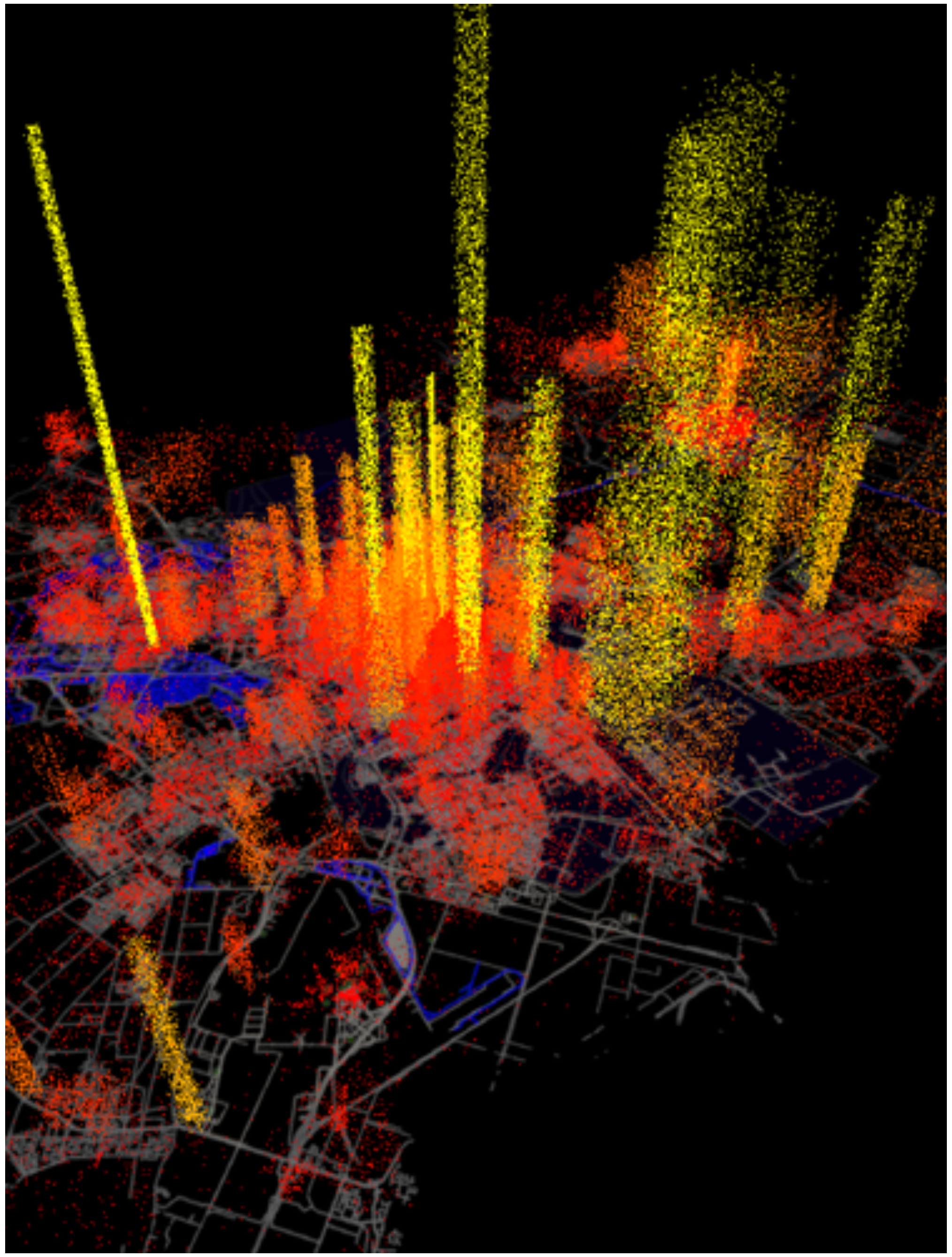
The world is urban

Majority of world population in urban areas
- 80% in developed countries
- Cities heterogeneity

Over-density challenges societies
- Saturation of public services
  - Efficiency - reactivity personalization
- Environnement and public health issues
  - Monitoring of the environment
- Transit time explosion and pollution
  - Public/private/individual transports

- Seamless Internet connectivity
  - <12% smartphones, > 82% bandwidth



ICT bring a physical-digital continuum

Sensors
- environnement
- activities

Smartphones
- passive tracking
- geolocalised services

Social networks
- active tracking
- direct interaction

Open data
- information redistribution
- digital maps
- real-time statistics

HubCab.org (c) MIT Senseable City
Statistics on cab fares in NYC

Smartness basis is data

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sensed

Smartness basis is data

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Smart-cities rely on sensors

Dense deployment of IoT devices sensing the city
•Configuration/installation cost is an issue
•Wireless networking
•Autonomous devices (battery/harvesting, self-* protocols, …)

Many emergent industrial deployments
•Telemetering (electricity, water, …)
•Vehicule detection (ITS, parking,…)
•Environnemental sensing (pollution, noise, …)

Challenges
•Constrained deployment
  •Social acceptability / EM pollution / Robust embedding
•Multi-application network
  •Performance / Privacy / Data ownership
•Urban environment
  •Unstable communications / Resiliency

GPSR [Karp et Kung, 2000]

What can be envisioned ?

Eg: structural health monitoring
•Bridges, skyscrapers, ….
•Maintenance planing

Today's situation
•Big and expensive sensors
•Expert deployment

New frontiers
•Nano-technology designed sensors
•Low-cost, small, inside concrete

New methodology: replace precision by number
•Environmental sensing (pollution, noise, …)
•ITS (Floating car data, fleet management, infrastructure monitoring,…)
•Mitigates data corruption attacks ?

Smartness is data moving

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Smartness is data moving

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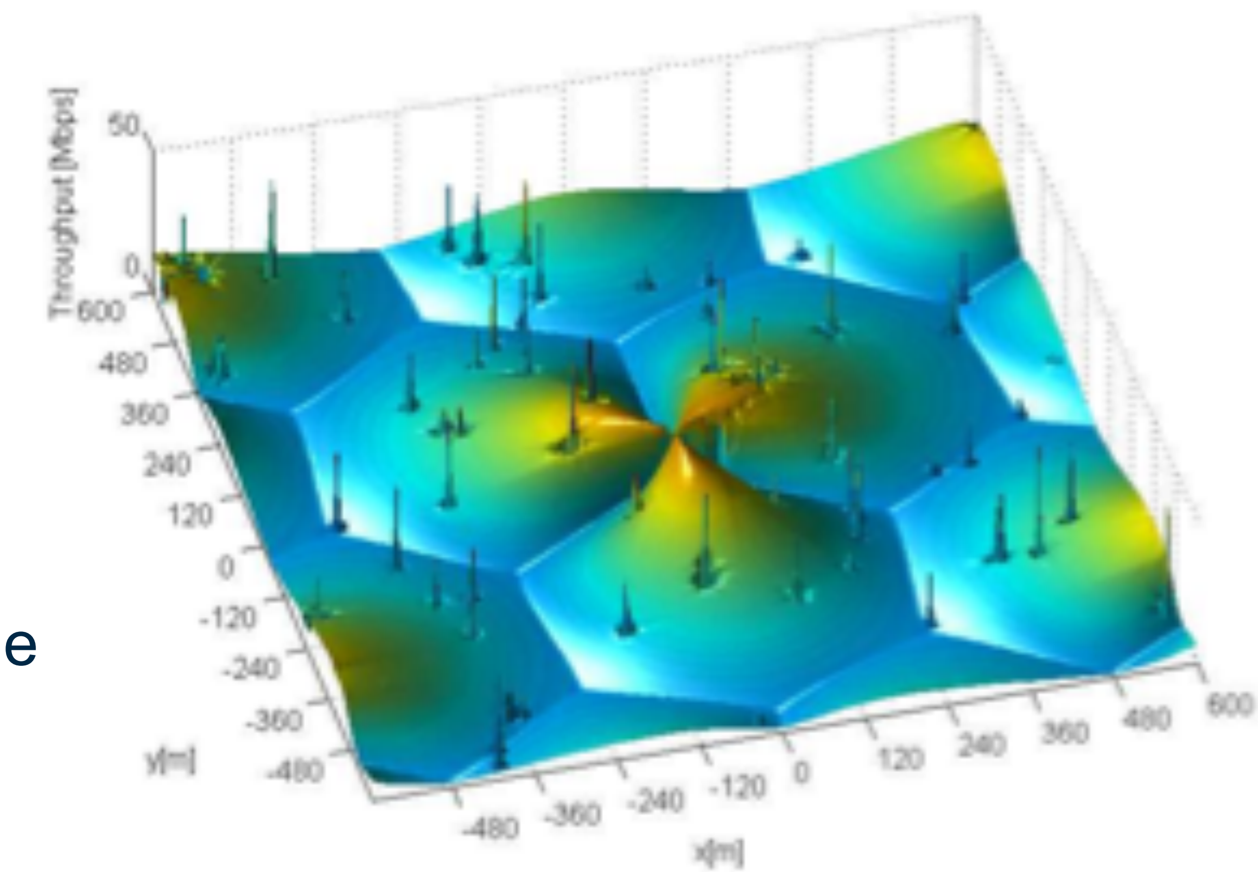
collect -process - redistribute

Cellular M2M connectivity



Large scale low power networks
•Ubiquitous covering, quite secure
•Uplink only, very low rate

Cellular network access unable to scale
•4G ressources are for mobile Internet
•Smartphone background trafic already an issue
•Unable to handle thousand of devices/cell

What evolutions ?
•Network densification coupled with RAN virtualization for efficiency
•Optimized access envisaged in 5G

Densification needs a smaller scale understanding of users
•Mobility at 10s of meters => urban layout critical
•Less users/cell => less statistical smoothing

Impact of femtocells on the network energy consumption

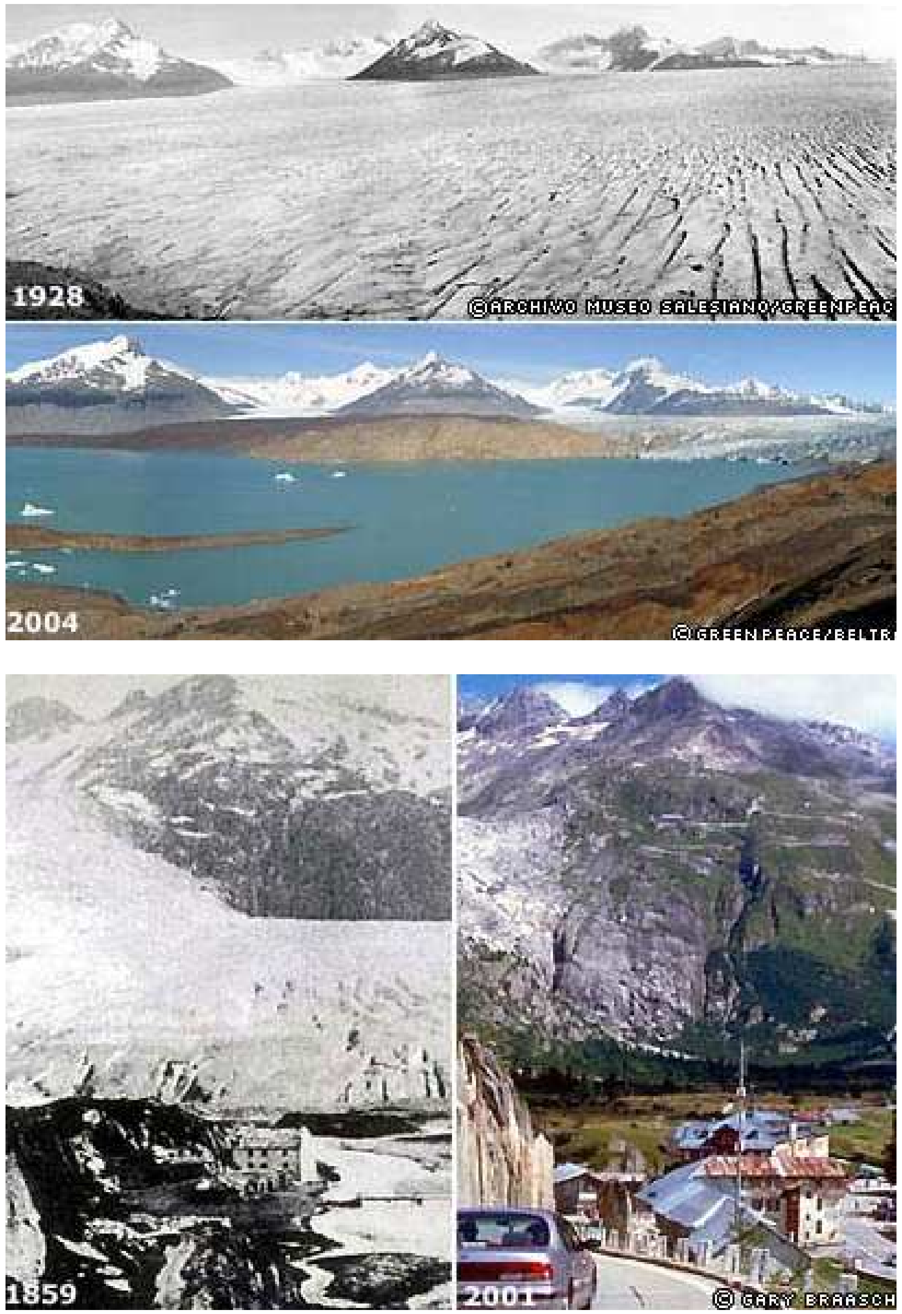
- Telecommunications is a large consumer of energy (e.g. Telecom Italia uses 1% of Italy's total energy consumption, NTT uses 0.7% of Japan's total energy consumption)
- Increasing costs of energy and international focus on climate change issues have resulted in high interest in improving the efficiency in the telecommunications industry

Opportunity:
Small cells have the potential to reduce the transmit power required for serving a user by a factor in the order of 10^3 compared to macrocells.

Problem:
Most femtocells today are not serving users but are still consuming power:

50 Millon femtos x 12W = 600 MW ⟶ 5.2 TWh/a

Comparison:
- Nuclear Reactor Sizewell B, Suffolk, UK: 1195MW
- Annual UK energy production: ~400 TWh/a



Courtesy of Alcatel-Lucent Bell Labs

BIGDATACHALLENGE2015

Mobile Traffic Signatures in the Urban Landscape

Angelo Furno, Marco Fiore, Razvan Stanica

TIM

Mobile Phones in Every-day Life

Mobile Phones in Every-day Life

THE URBAN LANDSCAPE AFFECTS THE TELECOMMUNICATION ACTIVITY OF MOBILE USERS

Motivations

➔ **Urban landscape affects telecommunication activity** of mobile users...

- aggregate mobile traffic differs across neighborhoods of a same city
- usage of mobile services depends on land use and daytime
- social events induces fluctuations in routine mobile traffic

➔ ...reverse-engineer mobile traffic demand

classify urban areas according to their mobile traffic activity

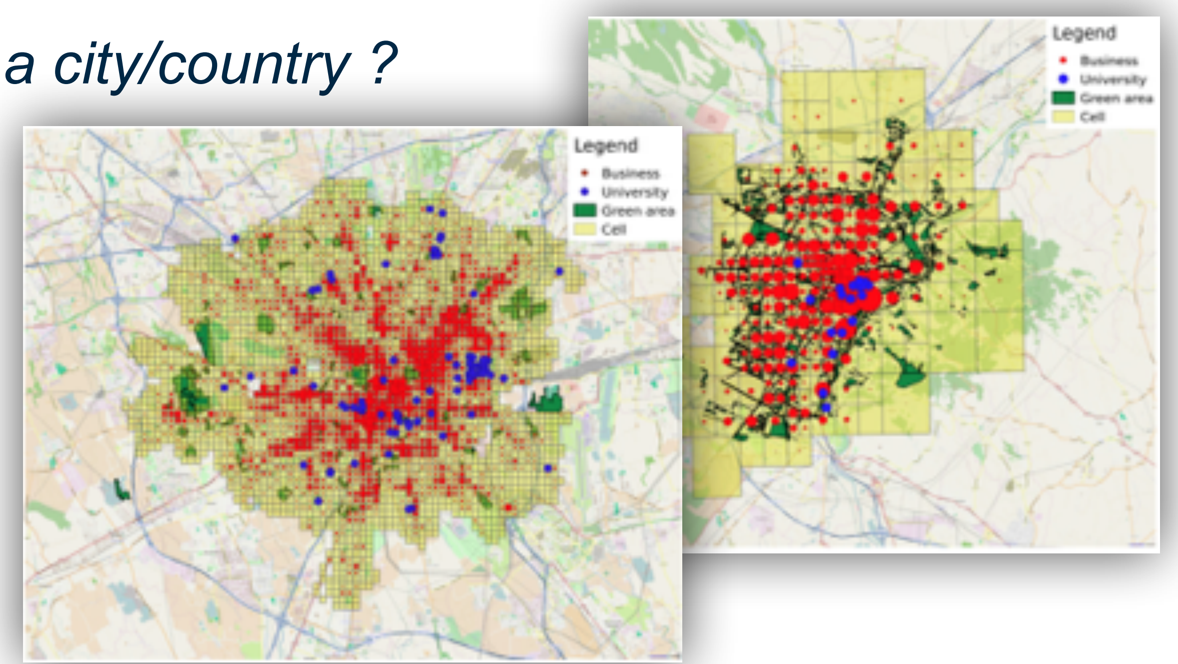
Goal

➔ Establish affinities between mobile traffic demand and urban tissue

➔ **Associate precise mobile traffic dynamics to specific urban landscapes**

urban landscape – combination of urban infrastructure (transport, education, healthcare, sports, etc.) and land use (residential, commercial, industrial, etc.)

- *Mobile traffic activity in proximity of a train station ?*
- *Different mobile traffic activities for train stations in a city/country ?*
- *Residential or touristic area ?*
- *University campus or sport arena ?*
- *Social reason behind dynamics ?*



➔ Results of **general validity**,10 cities in Italy & France

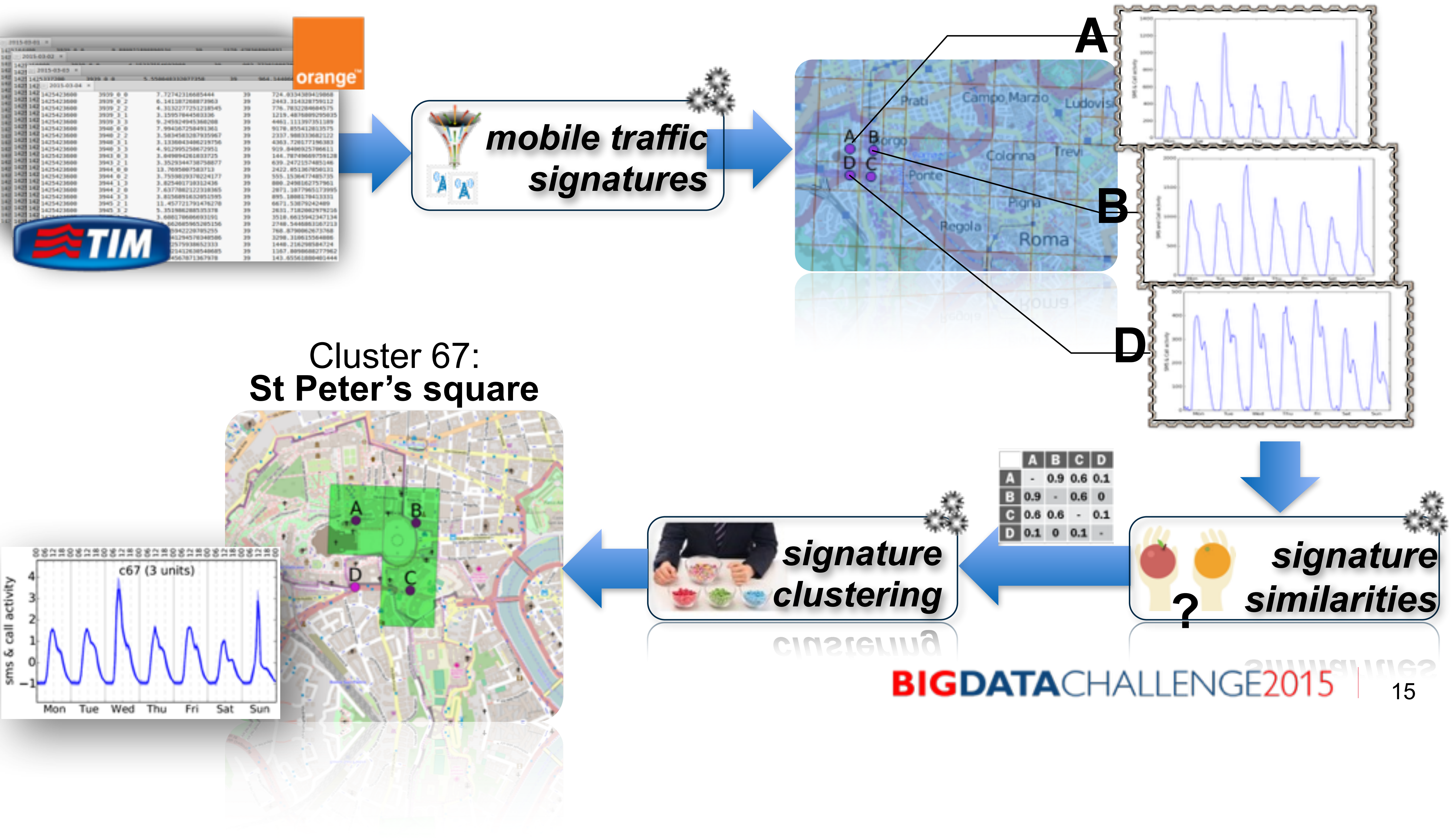
Mobile Data for Urban Classification

Mobile Data for Urban Classification

Mobile Data for Urban Classification

	A	B	C	D
A	-	0.9	0.6	0.1
B	0.9	-	0.6	0
C	0.6	0.6	-	0.1
D	0.1	0	0.1	-

Mobile Data for Urban Classification



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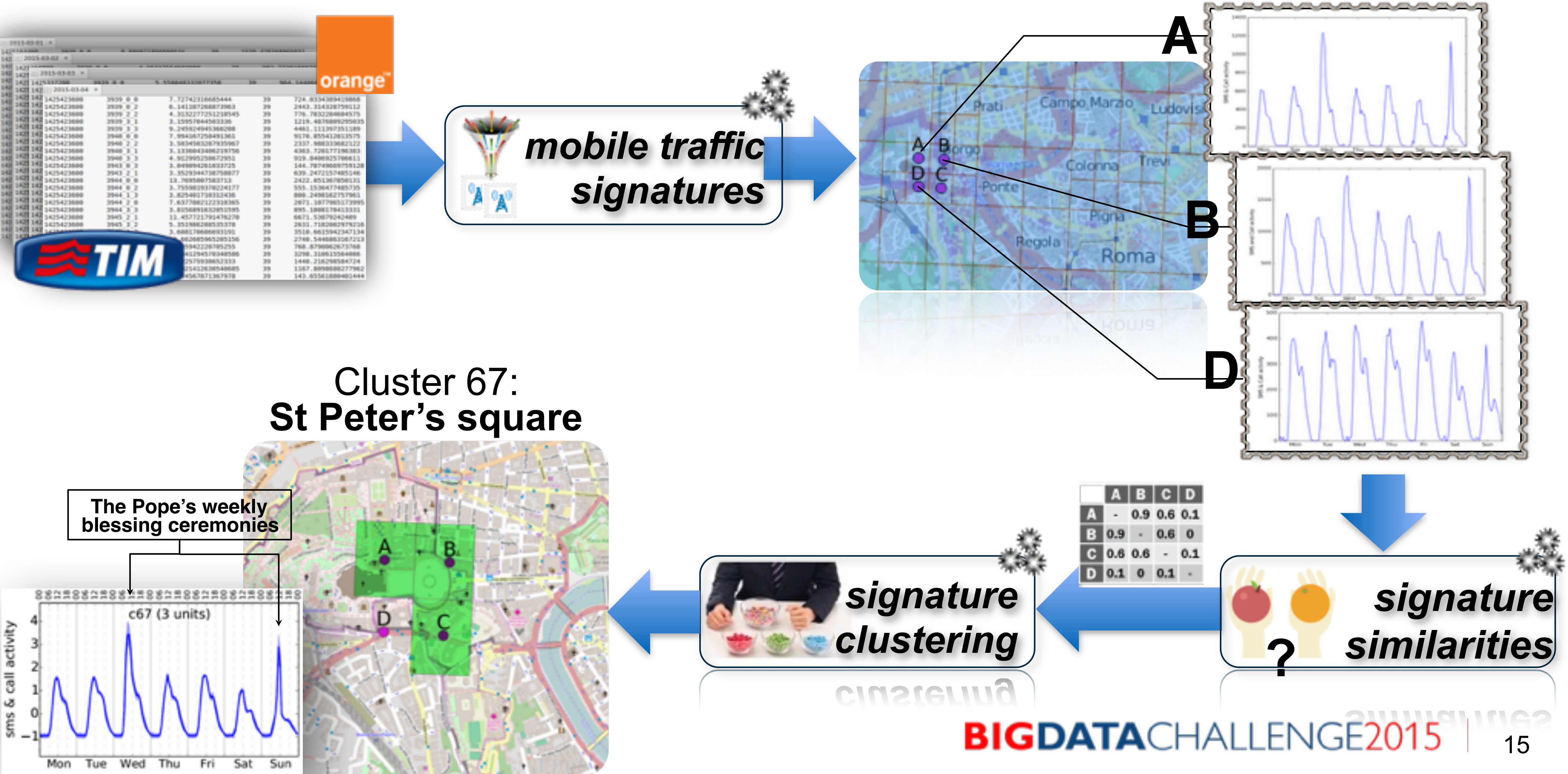

	A	B	C	D
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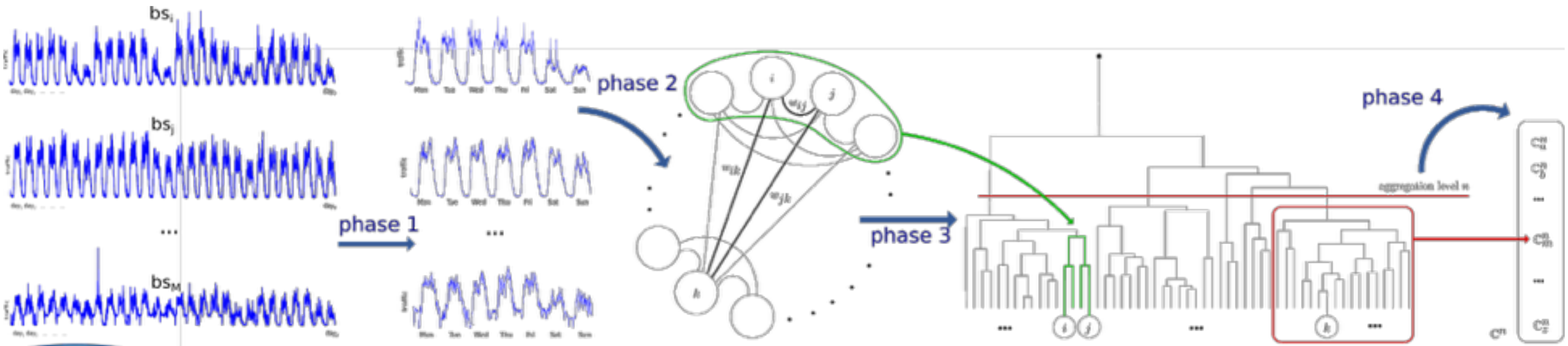
B	0.9	-	0.6	0
C	0.6	0.6	-	0.1
D	0.1	0	0.1	-

Idea

➔ We define the mobile traffic dynamics that characterize a given urban landscape as the **mobile traffic signature** of that landscape

➔ Our framework entails the following steps

1. Formal definition of *“mobile traffic **signature**”*
2. Formal definition of *“pairwise signature **similarity**”*
3. **Clustering** of mobile traffic signatures into classes, according to their level of similarity
4. Extraction of the mobile traffic signatures in large-scale geographical (urban) areas



Technical description

➔ Formal definition of *"mobile traffic signature"* – **Median Week Signature (MWS)**

$$\mathcal{V}_a = \{v_a(d,i) \mid \forall d \in \mathcal{D}, \forall i \in \mathcal{I}\}$$

a : area traffic refers to (e.g. base station, grid element)

$$\mathcal{W} = \{\text{MON,TUE,WED,THU,FRI,SAT,SUN}\}$$

$$\mathcal{D}^w = \{d \mid d \in \mathcal{D}, d = w\}$$

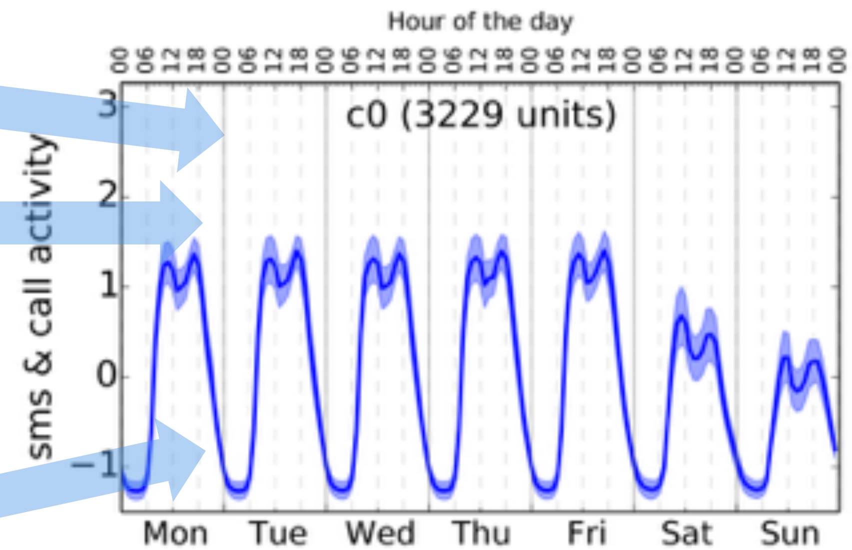
$$\hat{\mathbf{s}}_{\mathbf{a}}(t) = \hat{\mathbf{s}}_{\mathbf{a}}(w,i) = \mu_{1/2}\left(\{v_a(d,i) \mid \forall d \in \mathcal{D}^w, \forall i \in \mathcal{I}\}\right)$$

$$\mathbf{s}_{\mathbf{a}}(t) = \frac{\hat{\mathbf{s}}_{\mathbf{a}}(t) - \mu_{\hat{a}}}{\sigma_{\hat{a}}}$$

dataset

one-week support

per-hour normalized median values



➔ Formal definition of *"pairwise signature similarity"* – **Pearson's Correlation Coefficient**

$$p_{ab} = \frac{\sum_{t\in\mathcal{T}} (\mathbf{s}_{\mathbf{a}}(t) - \mu_{\hat{a}}) \cdot (\mathbf{s}_{\mathbf{b}}(t) - \mu_{\hat{b}})}{\sqrt{\sum_{t\in\mathcal{T}} (\mathbf{s}_{\mathbf{a}}(t) - \mu_{\hat{a}})^2} \cdot \sqrt{\sum_{t\in\mathcal{T}} (\mathbf{s}_{\mathbf{b}}(t) - \mu_{\hat{b}})^2}}$$

➔ Clustering of mobile traffic signatures into classes – **Hierarchical Linkage Clustering**

Used data

Telecom Italia Big Data Challenge 2014 – voice and text volumes per grid cell

Telecom Italia Big Data Challenge 2015 – voice and text volumes per grid cell (from the datasets "TIM - Telecommunications - SMS, Call, Internet" and "TIM – Grids")

10 city case studies

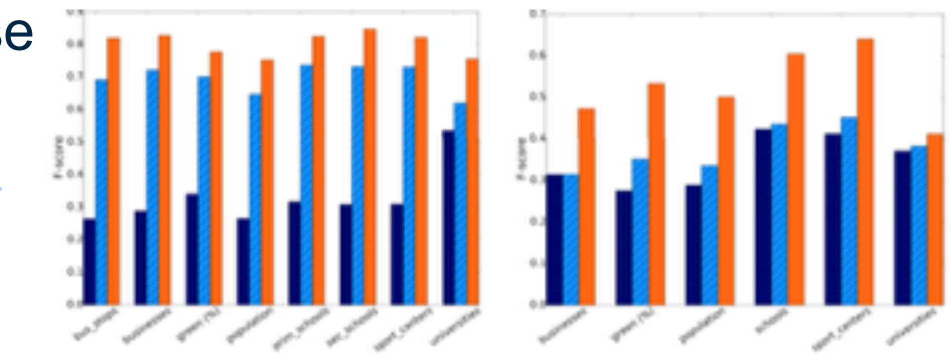
ID	*Source datasets*	*City*	*Unit Areas*	*Reference Period*
Mi-13	TIM 2014	Milan	2763 cell grids	Nov. and Dec. 2013
Tn-13	TIM 2014	Trento	152 cell grids	Nov. and Dec. 2013
Mi-15	TIM 2015	Milan	434 cell grids	Mar. and Apr. 2015
Rm-15	TIM 2015	Rome	341 cell grids	Mar. and Apr. 2015
Tu-15	TIM 2015	Turin	257 cell grids	Mar. and Apr. 2015
Pa-15	OR 2015	Paris	1634 base stations	Aug. to Nov. 2014 and Mar. 2015
Ly-15	OR 2015	Lyon	278 base stations	Aug. to Nov. 2014 and Mar. 2015
Ma-15	OR 2015	Marseille	188 base stations	Aug. to Nov. 2014 and Mar. 2015
To-15	OR 2015	Toulouse	220 base stations	Aug. to Nov. 2014 and Mar. 2015
Li-15	OR 2015	Lille	156 base stations	Aug. to Nov. 2014 and Mar. 2015
Bo-15	OR 2015	Bordeaux	158 base stations	Aug. to Nov. 2014 and Mar. 2015

Orange – voice and text volumes per base station from call detail records (CDR)

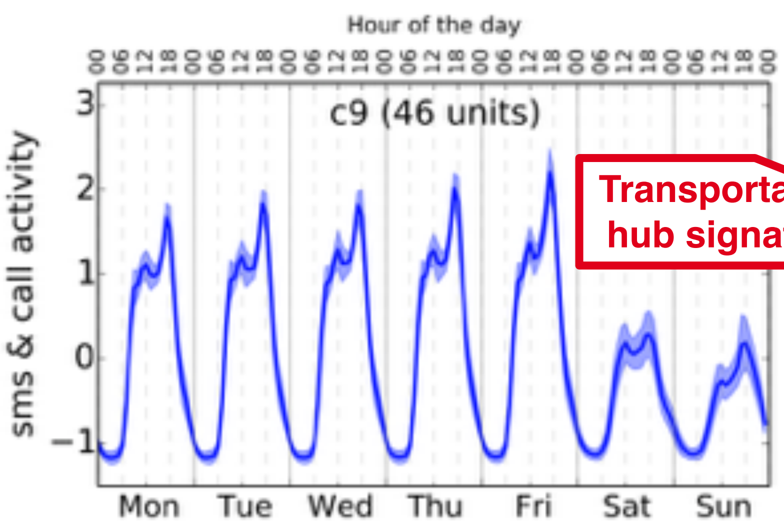
Main Outcomes (1)

- ➔ Signature definition: more accurate identification of urban landscape features
  - comparative evaluation against ground truth data on land use

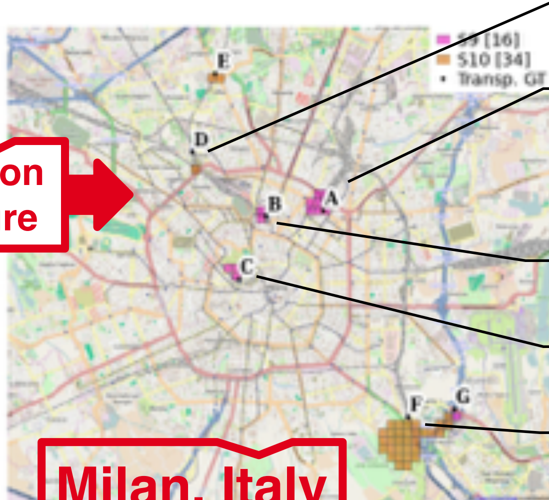
SOTO — competitor [7]
CICI — competitor [8]
MWS — ours


(a) Milan (b) Turin

- ➔ We identify **mobile traffic signatures** that are representative of important **urban landscapes**

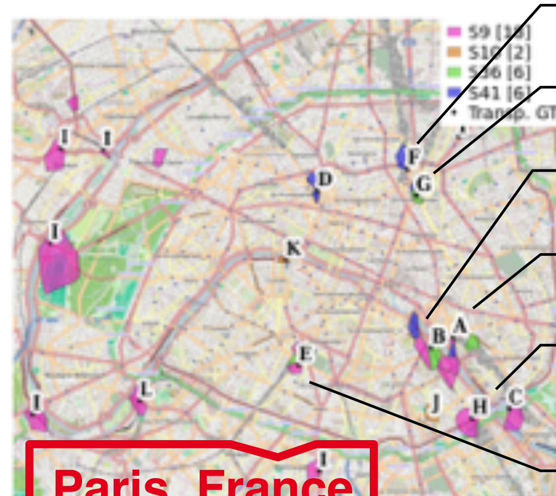


Transportation hub signature



Milan, Italy

Bovisa
Centrale
Porta Garibaldi
Cadorna
Rogoredo

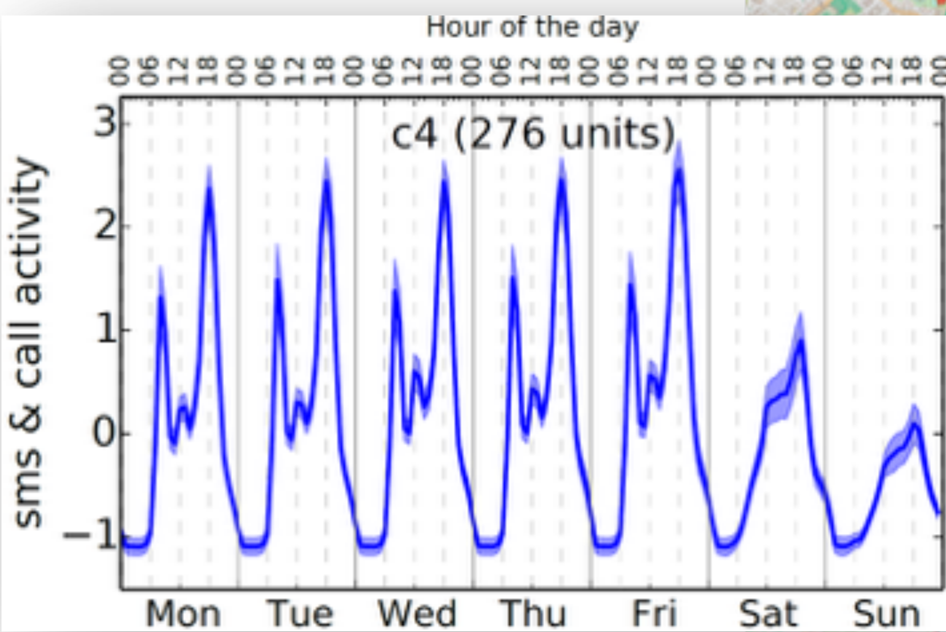


Paris, France

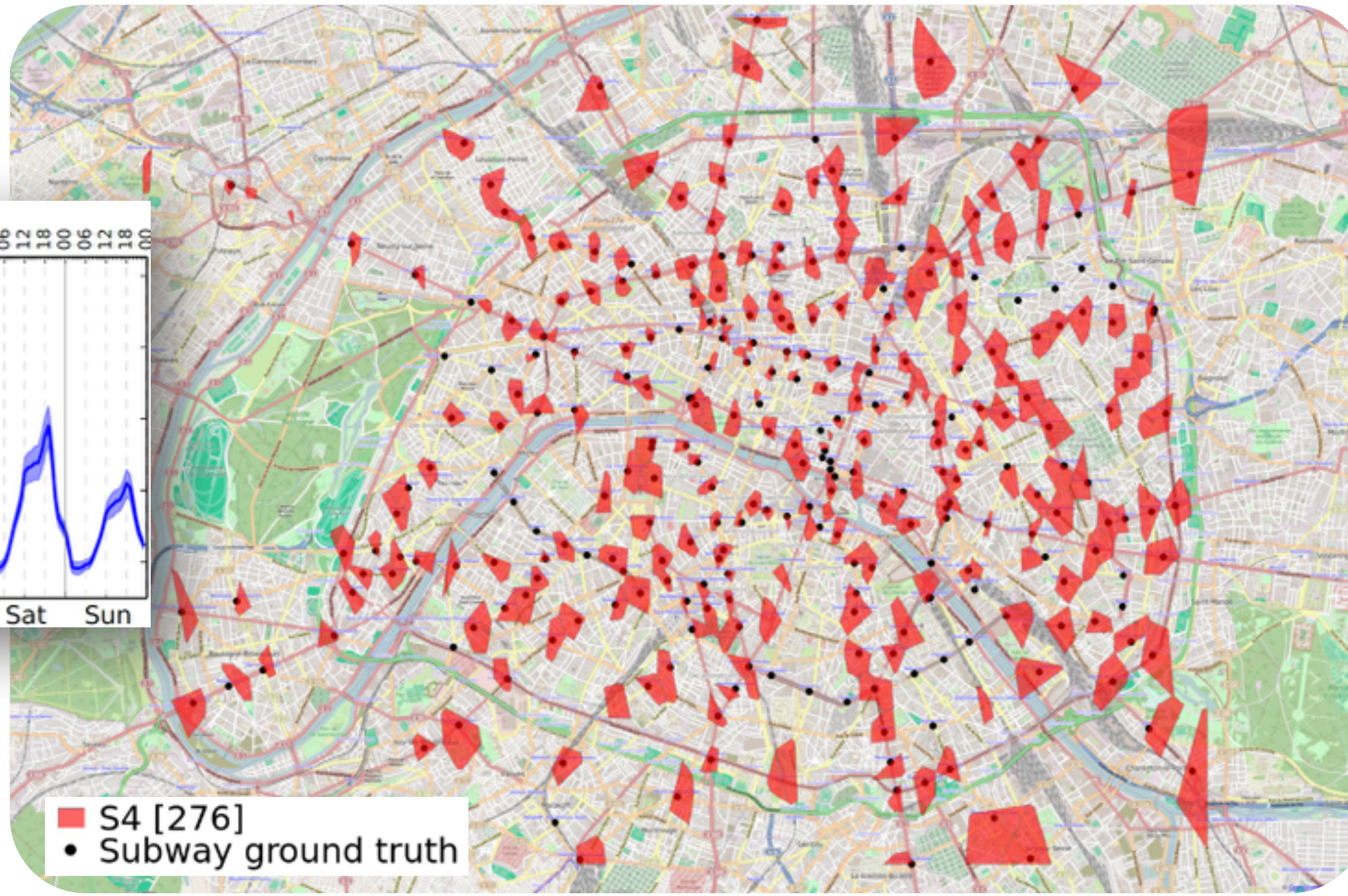
Gare du Nord
Gare de l'Est
Gare d'Austerlitz
Gare de Lyon
Major highway interchanges
Gare de Montparnasse

- ➔ Our results are consistent across all urban scenarios considered

Main Outcomes (2)



Metro station signature



Impact

➔ **Mobile Networking**: **diverse macroscopic** network utilization **profiles** over space and time

Effective planning of the **radio** access **infrastructure**, and efficient **management** of network resources:
- **Associations between load** of base stations and its **surrounding urban layout**
- **Classification of cities** according to **baseline signatures, network-aware adaptive strategies**

➔ **Urbanism**: **classification** of **urban tissue** to **support environmental** and **economical policies**

Continuous and **dynamic monitoring** of spatial and temporal socioeconomic evolution

Generation of very **precise** and **up-to-date urban maps** for city planning

- Effective and efficient way to **automatically classify** the urban landscape
- **Lower cost** and **increased accuracy** than traditional survey methods for land use detection
- Requires only **geo-referenced anonymized traffic informations**
- Exploring **heterogeneous metropolitan** areas on a **larger scale** - much **finer precision**

Future evolution

➔ New **networking solutions - demand-aware provisioning**, **optimization** and **troubleshooting**

- **Leveraging** the **awareness** of the **urban landscapes** for network strategies
- **Profiling** the **dynamics** of the **demand** on a **per-service** basis.

Need a deeper understanding of the existing correlations between types of user-generated traffic and specific urban landscapes

➔ **Deeper exploring** the **correlations** between **multiple sources of data** and **urban landscapes**

- **Internet traffic,** direction of call/SMS, number of connected users…
- **Other countries** to assess urban landscape signatures
- **Other kinds** of **urban activities** (e.g. Wi-Fi, biking, etc.)

Mobility is added value

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Mobility is added value

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Leverage « free » mobility

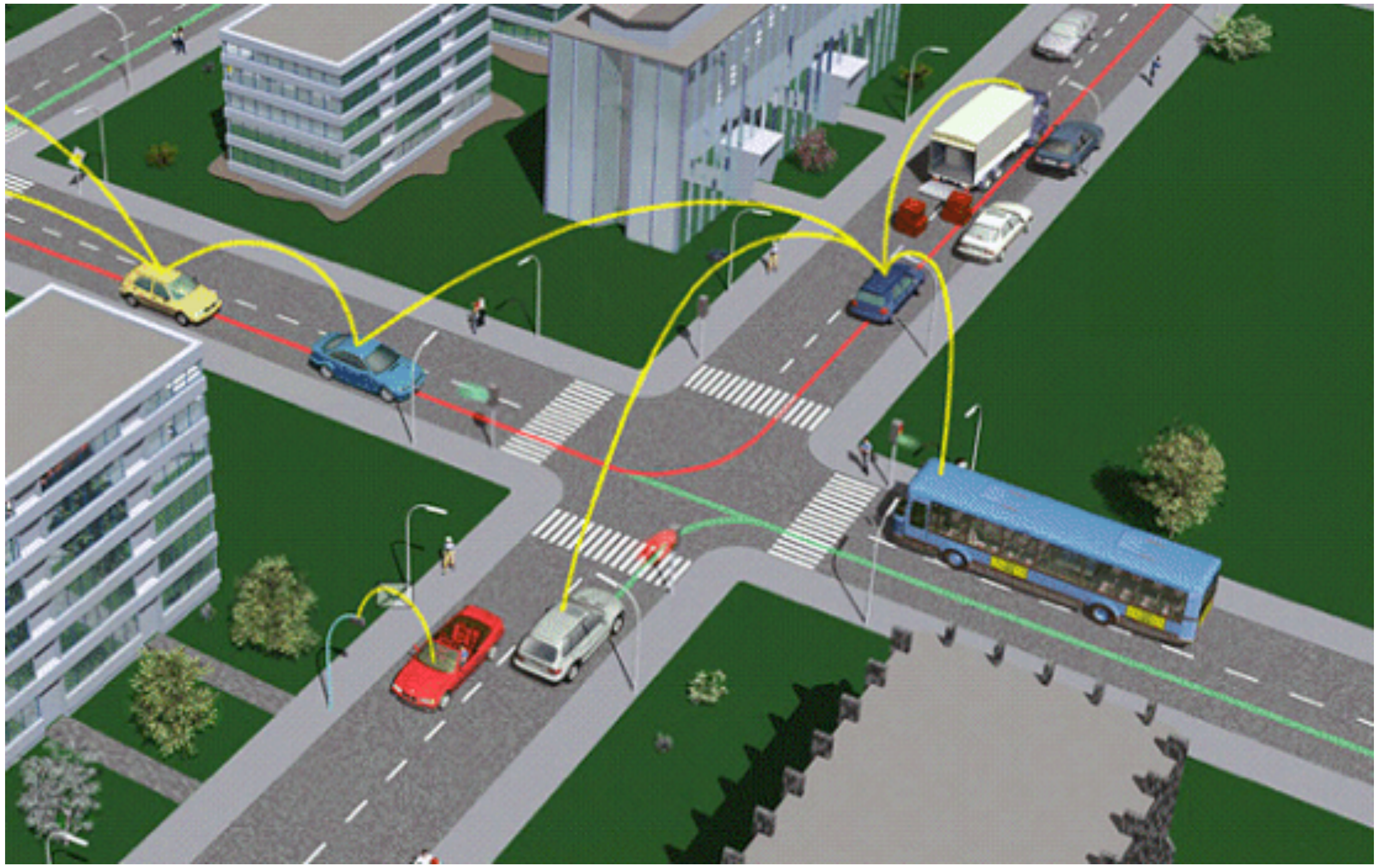
Leverage mobility: crowdsourcing

Many sensors are moving in the city
- •Smartphones
- •Cars / public transportations

Many low-precision vs few high-quality

Mobile sensors vs dense deployment

Sense where the citizens are



Already in play for basic ITS
- •GPS with trafic information, Google waze
- •Community informations on public services
- •Rogue players mitigation by consensus ?

Citizen empowerment - Democracy issue
- •Need a large basis of users to be effective
- •Equal right to participate or equal weight in the decision ?

An example: smart urban biking

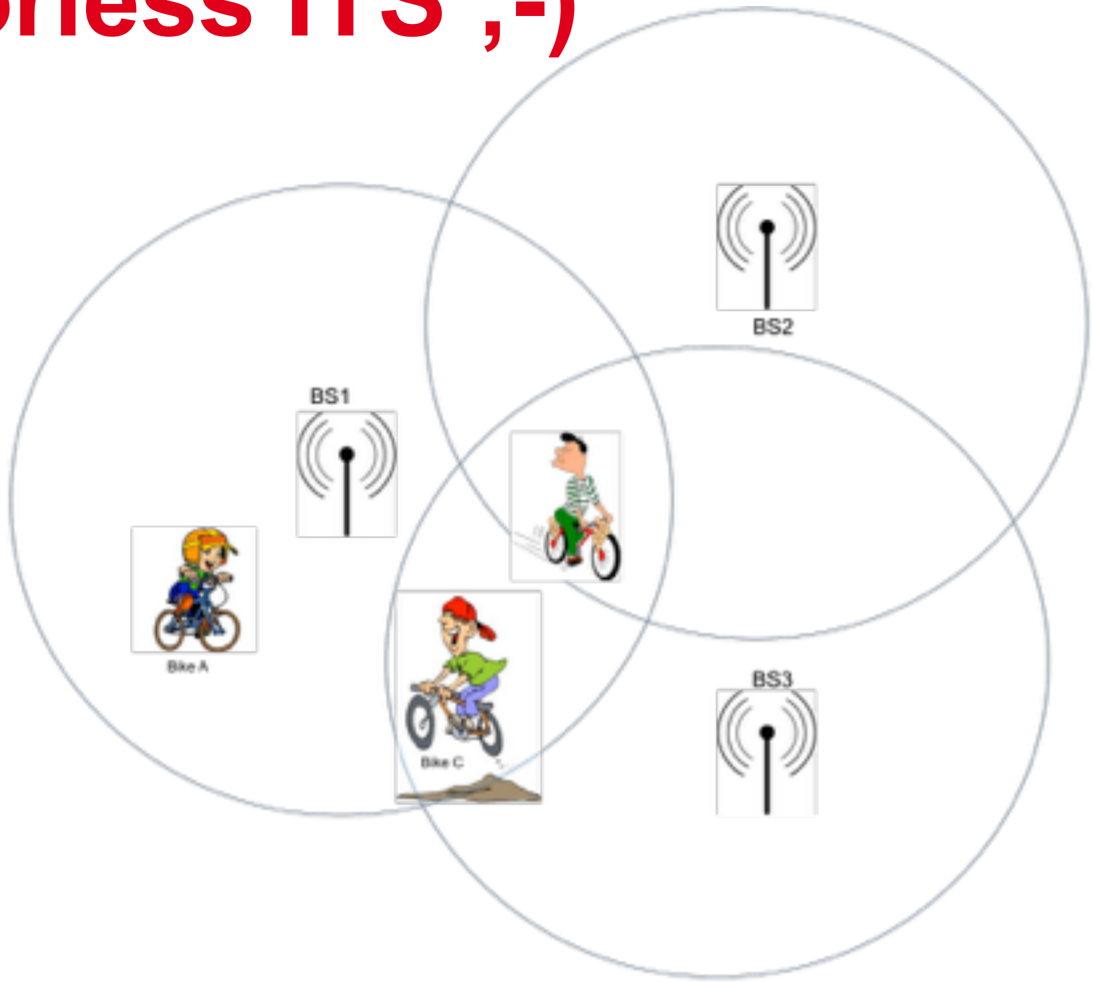
« Bikability » of cities : strong trend (mayor of Phoenix, USA)
•Contributes on health and decongestion

City wide bike sharing services are spreading
•73,5k 2008, 236k 2011, 517k 2014

Enablers for urban biking
•Infrastructure for confort and security. Dedicated lanes ~ 2M$/km
•Institutional informations, education. Top-down
•Enrollment in community (go from pioneering to citizenship)

Some market solutions
•« self-quantifying » applications for sport geeks
•Community applications
  •Road state, path comfort, localization of stolen bikes
•Institutional applications
  •Bike sharing stations availability
  •Open Data strategy

Instrumented bike - Motorless ITS ;-)



Technology enables today
•Light, low-cost, low-power bike instrumentation
•Sensing effort, position
•Non-intrusive in the mechanics (e.g. Connected bike at CES)

Leverage bike sharing infrastructures
•City-wide community from scratch

Many information available
•Self-* : raw data collected by user's smart-phone/watch
•Realtime system status : positions, station availability
•Decision algorithms : aggregated statistics on travels, state of road
•Tomorrow : pollution, surrounding trafic, …

Need for qualitative and quantitative understanding bikers behaviors
•Paths followed individually
•Flows of bikes
•First step : Privamov IMU project

Crowdsourcing (and urban IoT) issues

Dedicated sensor deployment is expensive (cost and time)
- Distributes the share on users (cynical)
- Empowers citizens and keep scalable (optimistic)

« For citizens » => « with citizens »
- Need for approval of a community
- Unfortunately includes rogue users

Several outcomes that needs pluridisciplinary research
- Network architecture evolution: heterogeneous capillary networks / User-centric design
- Services toward citizens: modeling impact on behavior to evaluate performances
- Decision aid mechanisms and policy assessment: physical models of urban environment

Privacy and security issues are huge !
- Smart devices = first entry point to your private sphere
- Freedom is at play - Democracy needs equality

Intelligences des Mondes Urbains
LabEx - IMU

UNIVERSITÉ DE LYON

IMU Intelligences des Mondes Urbains
UNIVERSITE DE LYON

IMU is a multidisciplinary research and experimentation cluster focused on cities, urban environments, metropolisation, and urbanisation - past, present, and future

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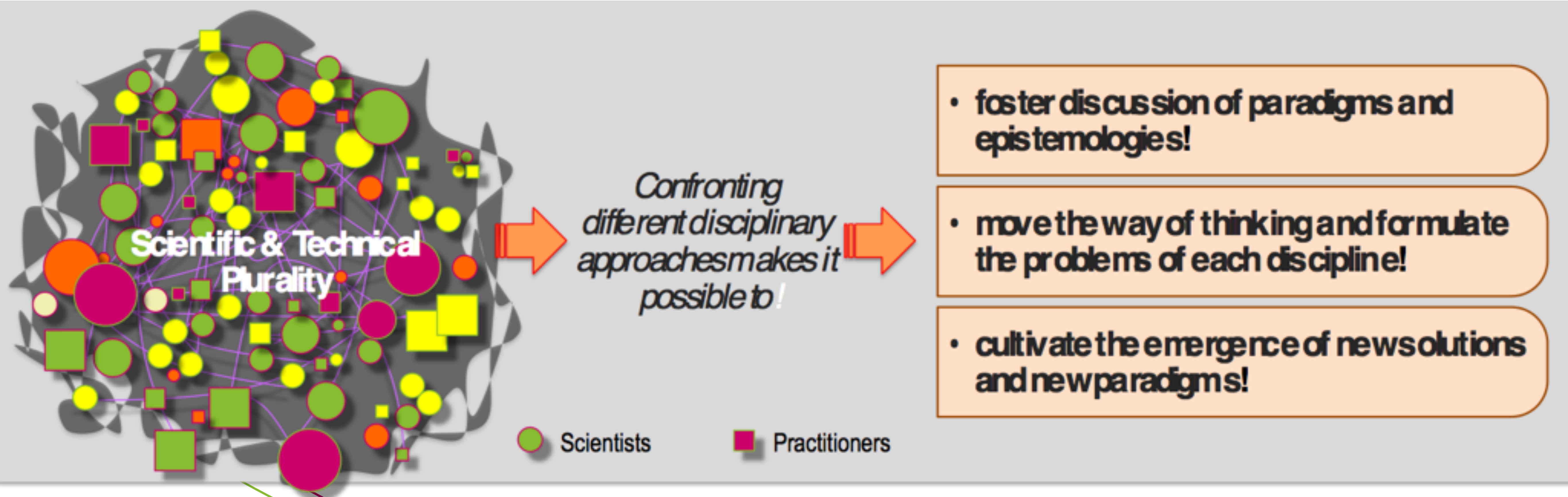
Scientific & Technical Plurality

The action, its knowledge and its problems are fundamental drivers of the understanding of urban worlds. IMU integrates practitioners from companies, local authorities, associations and their knowledge

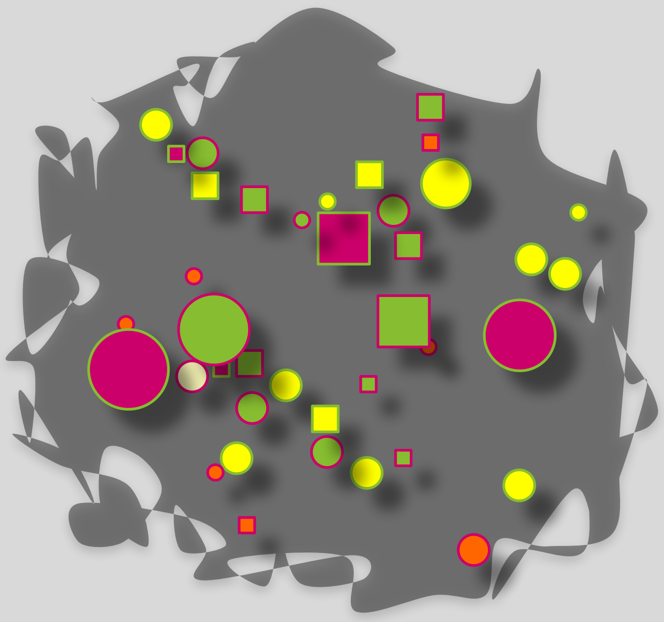
Inside IMU, the scientific and technical plurality is meant to be radical



The Lyon Saint-Etienne urban area offers **exceptional compendium of urban, environmental and ecological situations which are characteristic** of the contemporary dynamics of urbanisation and metropolisation

IMU Added Values

- Creation of a real and lively scientific multidisciplinary community working together in a pragmatic approach on concrete projects
- City and urbanisation established as a shared research object allowing researchers to enlarge their competences and know-how
- Increase of partnership opportunities within the community and with the practitioners



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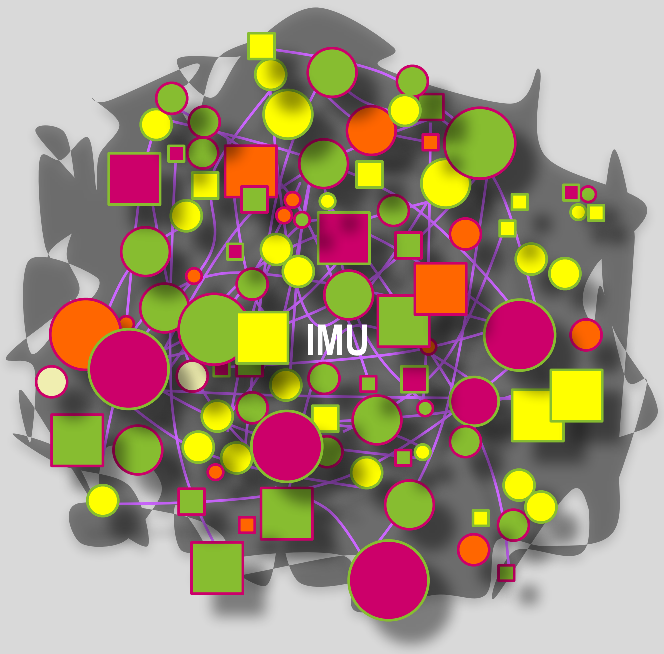

Scientific Activities

- **One call of project per year, since 2012**
  - A total of 71 submitted projects
  - 31 projects financed (2,91M€)
  - An average of 4 Ph.D. thesis and 5 post-docs financed per year
  - The projects are evaluated each year (reports analyzed by the scientific council)
  - 12 multidisciplinary publications in international journals
- Two calls for Master Thesis: 15 Thesis financed yearly
- More than 70 labeled conferences, workshops, books, exhibits, …
- IMU Alpha: scientific actions organised by Ph.D. students and young researchers (seminars, experimental workshops, dissemination,...)

Scientific Content of Calls of Projects

- Researchers & Practitioners ➔ emerging urban issues; reformulate research questions; define with the scientific council the content of the call of projects
- 6 topics defined by IMU community:
  - Nature in the city
  - Cities and mobilities
  - Building, construction, habitat
  - Digital city: from urban data to smart services
  - Urban risks and environment
  - Future urban worlds, possible urban worlds
- and one open-topic

INTERNATIONAL

Université de Lyon
PROJET IDEX 2 LSE

Région RhôneAlpes

GRANDLYON la métropole

Intelligent Urbanization Cocreation Center
IUCC

CHINA
Shanghai
Tongji University

GreenBuilding (August 2013)
Partnership with IUCC -Tongji
Welcoming M. Chen Yang (March 2014)
IMU visits China
(October 2014)

Villes Régions Mondes
VRM

CANADA
Montréal, Laval,
INRS

Urban and spatial studies
Partnership agreement with the Network « Villes Régions Monde » (VRM) in Montréal
(July 2012)

SAO PAOLO University
USP

BRAZIL
Sao Paulo
USP

First Lyon-Sao Paulo research workshop :
« Sustainable City, Urban Vulnerability, Urban Mobilities »
13 to 15 November 2013
IMU visits Brazil (October 2014)

IMU
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DISSEMINATION

TUBA (Living Lab) : A tube for urban experiments

- An association of public and private actors to imagine new services and uses based on urban data
- A place where ideas and technologies meet citizen needs to imagine and experiment smart cities

- IMU co-invented TUBA with « Grand Lyon » and companies such as EDF, VEOLIA, Keolis, SFR, SOPRA
- IMU participates to the scientific council and board meetings

Thanks

team.inria.fr/urbanet/

www.citi-lab.fr/team/urbanet/

Inria

INVENTEURS DU MONDE NUMÉRIQUE

INSA INSTITUT NATIONAL DES SCIENCES APPLIQUÉES LYON

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