Cell Traffic Prediction Using Joint Spatio-Temporal Information

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Outline

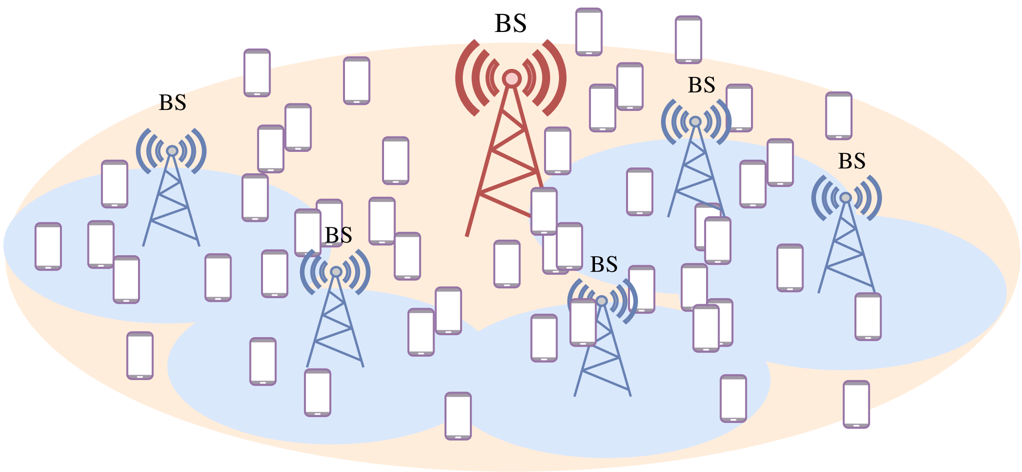
- Contribution
- Prediction techniques
- Cell load prediction
  - The dataset
  - Results
- Conclusions

Prediction in Cellular Networks

Anticipatory networking

Predict future network states
and optimize the network

Focus on cell load prediction,
enabling smart load balancing



Contribution

- State-of-the-art techniques use
  - Traffic in time in a single base station (BS)
  - Call Data Records (i.e., network level information)
  - Spatial information
  - Analytical, closed-form, simplified models

We apply machine learning techniques combining spatial and temporal information

- 10 minutes granularity
- Improved prediction in noisiest scenarios

Spatio-temporal neighborhood

Given two points (i, j) characterized by their position (x, y) and time t, let the distance $d_{i,j}$ be

$$d_{i,j} = \sqrt{\left(\frac{x_i - x_j}{d_0}\right)^2 + \left(\frac{y_i - y_j}{d_0}\right)^2 + \alpha\left(\frac{t_i - t_j}{T}\right)^2}, \quad (1)$$

Inter-cell distance

Sampling interval

The spatio-temporal neighborhood N_m^β of point m is the set of points at a distance smaller than β

$$N_m^\beta = \{p : d_{m,p} < \beta\}. \quad (2)$$

Indicators

For the prediction at time t of the load at cell m use

- the value of the cell load z_p for each point $p \in N_m^\beta$
- three indicators
  - Weighted mean $$\omega(N_m^\beta) = \frac{1}{|N_m^\beta|} \sum_{p \in N_m^\beta} \frac{z_p}{d_{m,p}} \quad (3)$$
  - Spread $$\sigma(N_m^\beta) = \sqrt{\frac{1}{|N_m^\beta|} \sum_{p \in N_m^\beta} (z_p - \bar{z})^2}, \quad (4)$$
  - Weighted tendency $$\tau(N_m^{\beta_1,\beta_2}) = \frac{\omega(N_m^{\beta_1})}{\omega(N_m^{\beta_2})}. \quad (5)$$

Prediction techniques: regression

Simple and efficient techniques

- Multiple linear regression (least square loss)
- Regularized linear regression (avoid overfitting)
  - Ridge – square penalty
  - Lasso – linear penalty
  - Elastic net - combination of the previous

Prediction techniques: ML

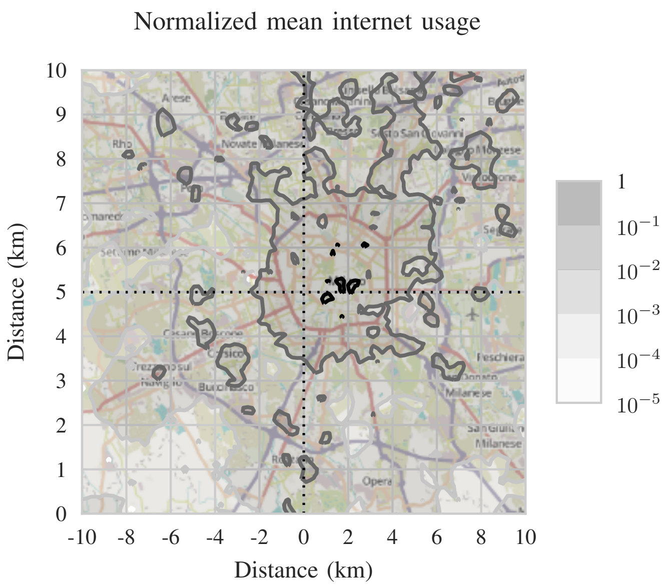
More complex algorithms

- Support Vector Machines (SVMs) with Support Vector Regression techniques
- Random Forest (RF)
- Neural Networks (NNs) with stochastic gradient descent method for back-propagation

The dataset

Telecom Italia Big Data Challenge 2014 dataset

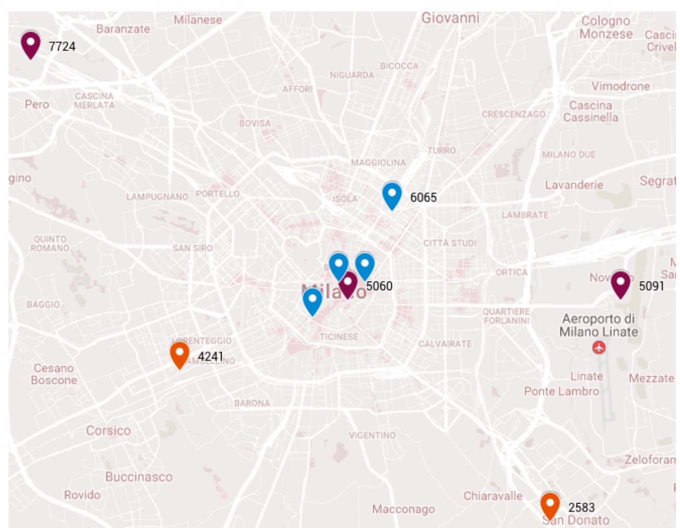
- Records of internet usage in Milan
- 2 months of data (Nov and Dec 2013)
- Grids of cells with $d_0 = 200$ m
- Sampling interval $T = 600$ s



Cells analyzed

For computational reasons, we considered 9 representative cells:

- 2583, 4241 average traffic close to the average over the whole city (orange)
- 5060, 5091, 7724 high peak usage (red)
- 4856, 5259, 5262, 6065 high average traffic (blue)



Parameters optimization

- Exhaustive search
- 10-fold cross-validation
- α and β optimized for each cell (up to 46 neighbors)

Parameter	Value	Description
λ_R	[1.637e-6, 0.074]*	Ridge regularization parameter
λ_L	[1e-06, 4.665e-6]*	Lasso regularization parameter
$\lambda_{R,E}$	[0, 1.105e-5]*	Ridge regularization (elastic net)
$\lambda_{L,E}$	[0, 4.665e-6]*	Lasso regularization (elastic net)
C	[0.22, 34.081]*	SVR linear kernel penalization term
N_t	200	Number of RF trees
γ	10^{-3}	NN learning rate
N_{iter}	10^4	Maximum NN iterations
ε	10^{-10}	NN convergence tolerance

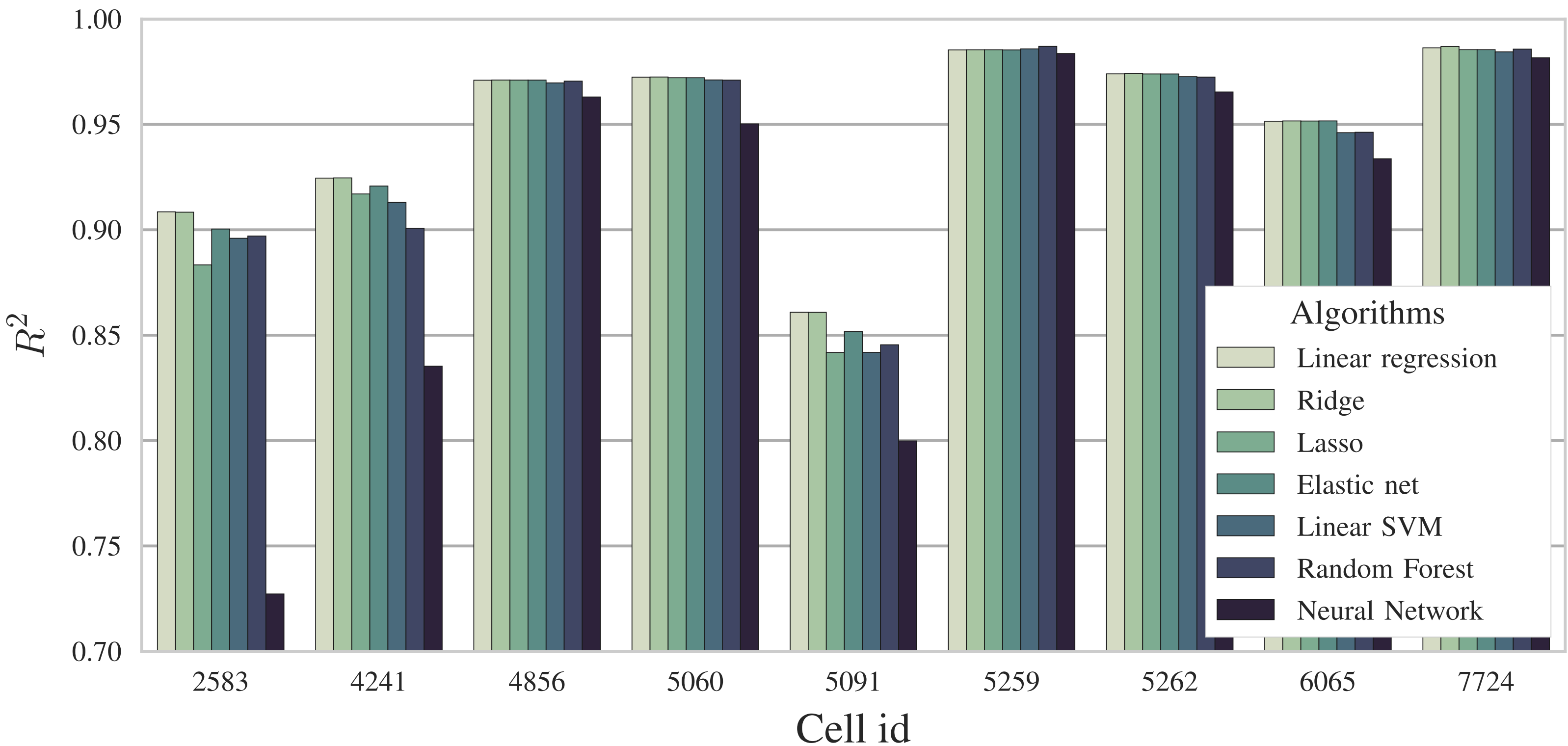
*These parameters were optimized for each cell.

TABLE I
PARAMETERS USED IN THE SIMULATION.

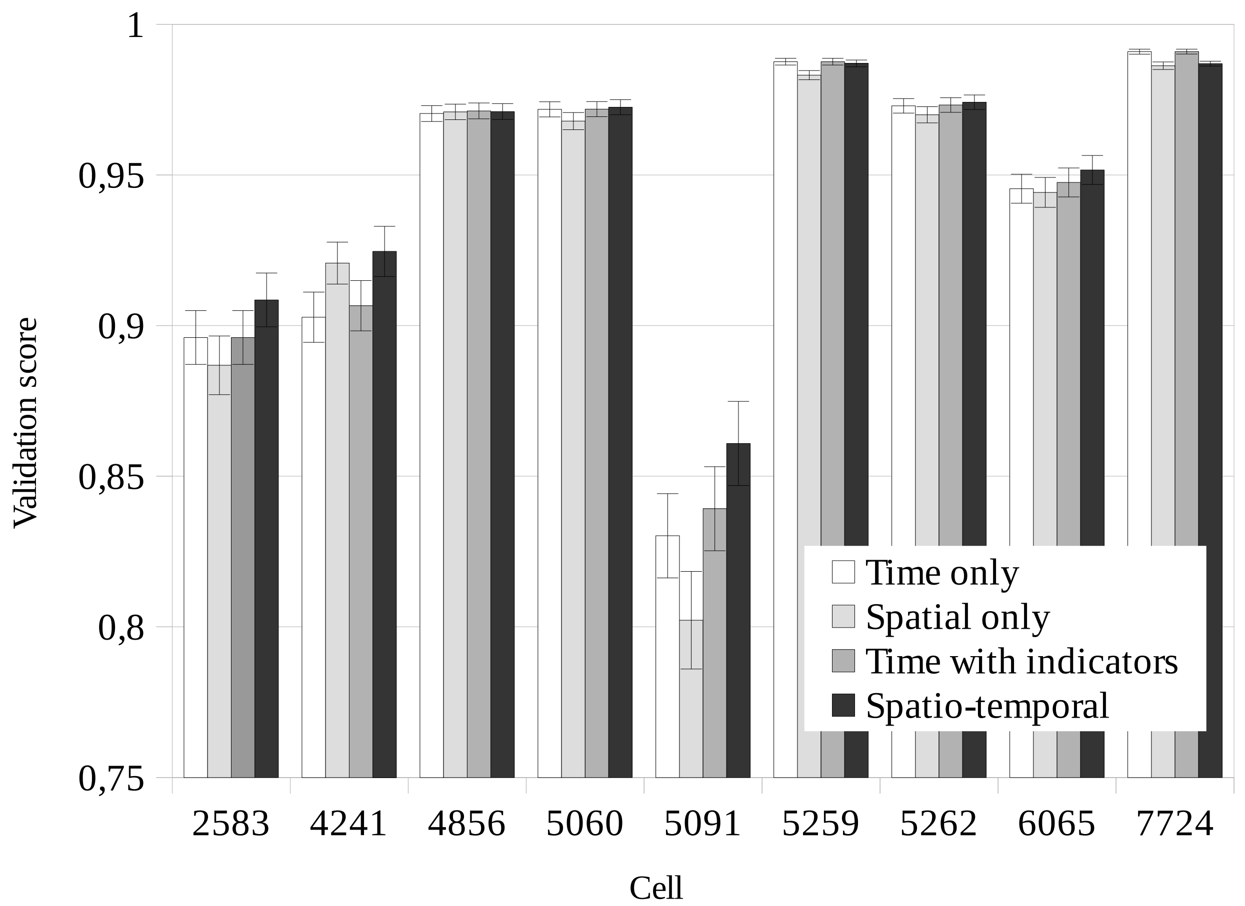
Cell id	α	β	Number of neighbors
2583	0.25	2	27
4241, 4856	2.25	3	25
5060	0.09	2	46
5091	0.19	2	28
5259, 5262, 6065	0.12	2	37
7724	0.19	2	28

TABLE II
OPTIMAL NEIGHBORHOOD DEFINITION FOR EACH CELL.

Prediction methods comparison



Prediction methods comparison



Cells 2583, 4241, 5091 are close to major traffic roads or hubs

Spatio-temporal information improves prediction accuracy

Conclusions

- Real data from Telecom Italia network
- Simplest and most efficient methods give best results
- Spatio-temporal information improves prediction in high mobility scenarios
- Future work
  - More systematic study of the dataset
  - Introduction of new indicators
  - In-depth study of neighborhood size impact

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