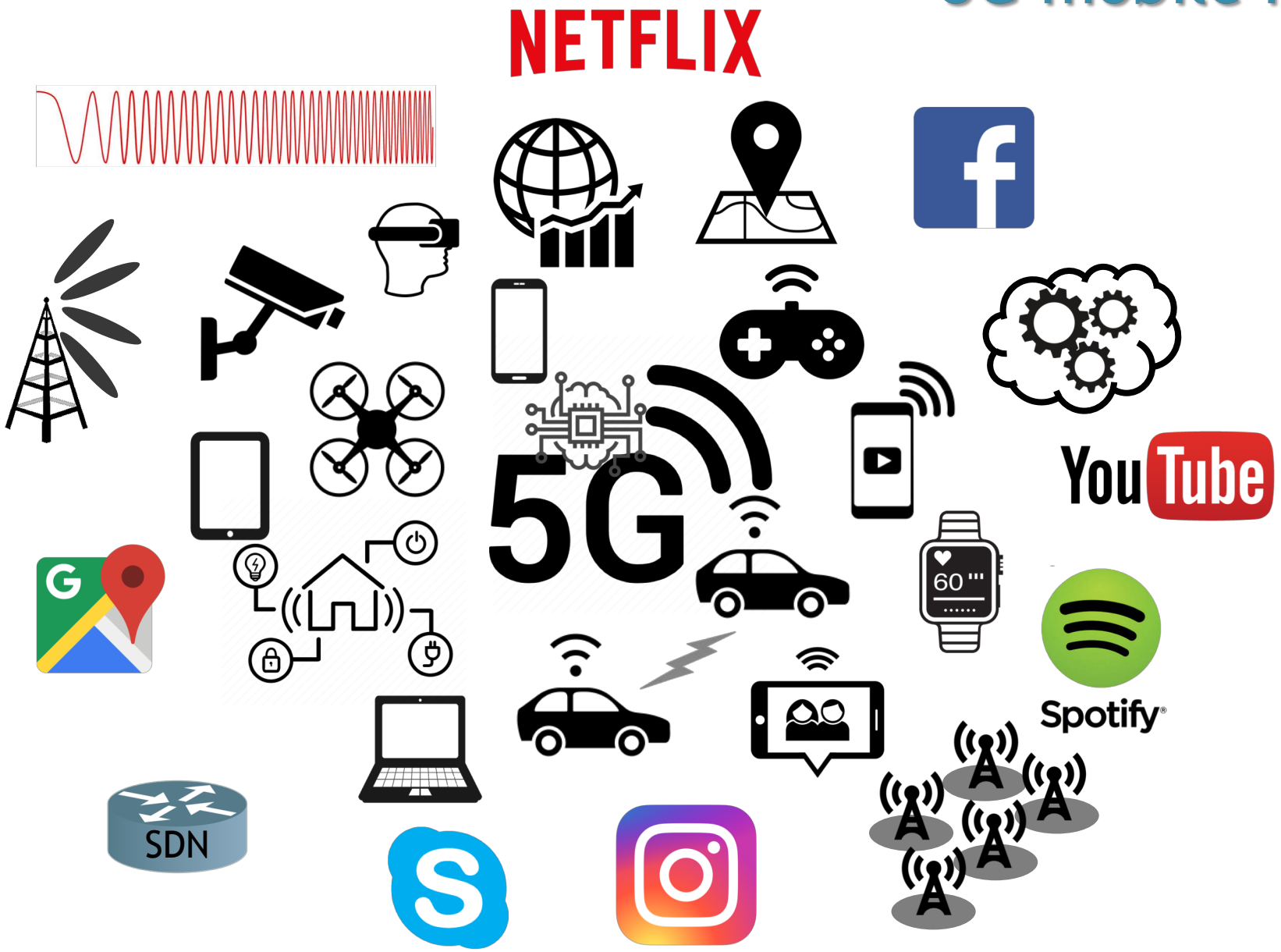
α-OMC: Cost-Aware Deep Learning for Mobile Network Resource Orchestration

Dario Bega[1,2], Marco Gramaglia[2], Marco Fiore[3], Albert Banchs[1,2] and Xavier Costa-Perez[4]

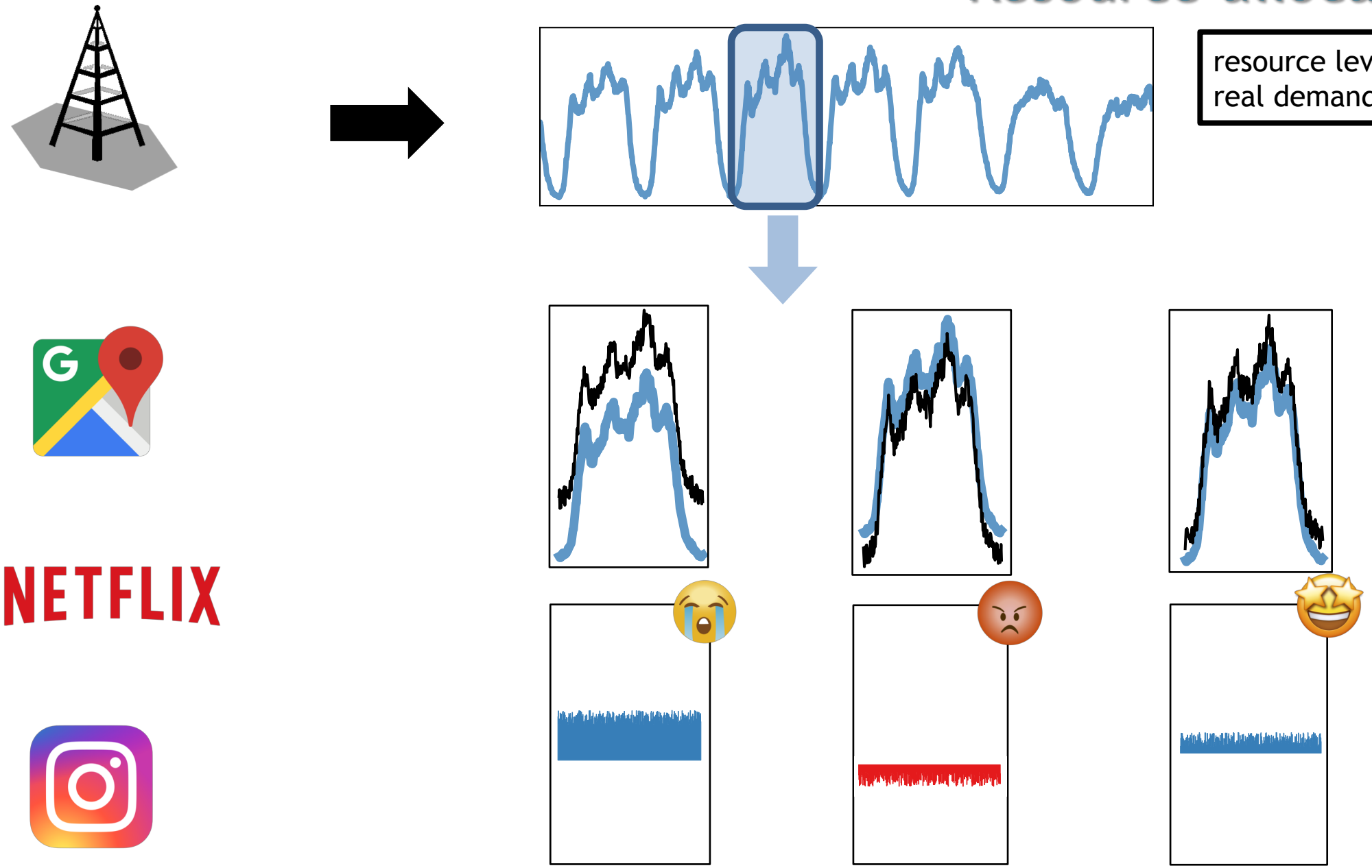
[1]*Institute IMDEA Networks, Madrid, Spain*
[2]*University Carlos III of Madrid, Madrid, Spain*
[3]*CNR-IEIIT, Italy*
[4]*NEC Laboratories Europe, Heidelberg, Germany*

[Developing the Science of Networks]

5G mobile networks



Resource allocation

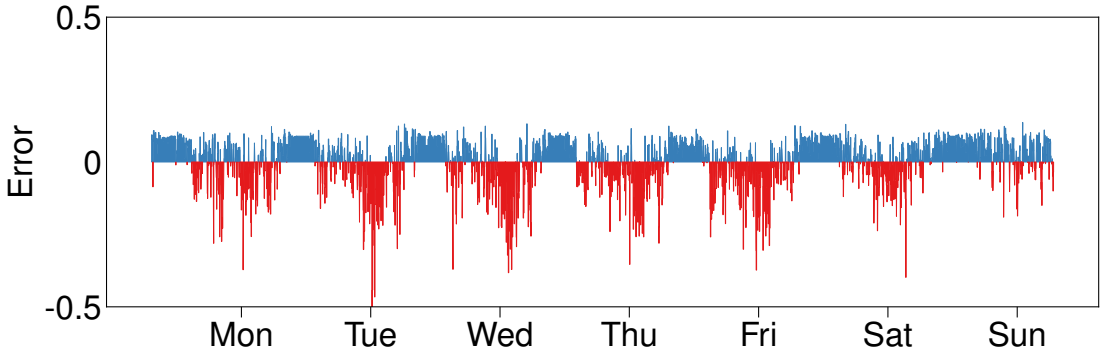


CAPACITY FORECASTING

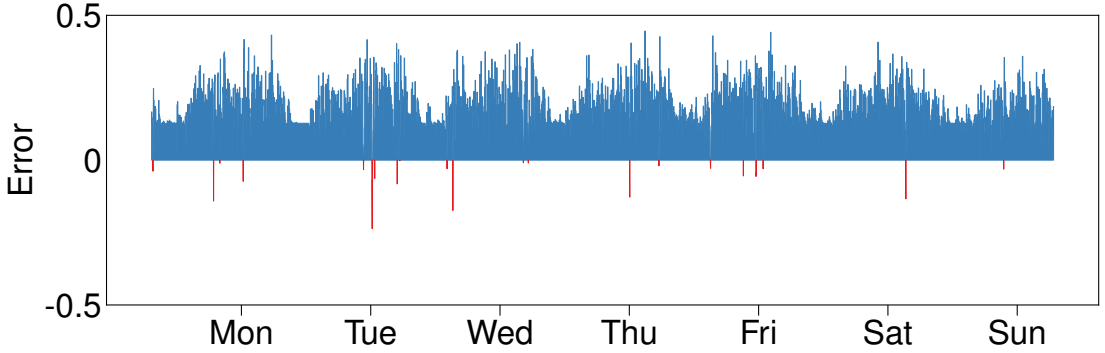
Capacity Forecasting

- Traditional approaches deal with demand forecasting

A traffic demand forecasting algorithm aims to minimize the error wrt to the original data, so underestimation is possible

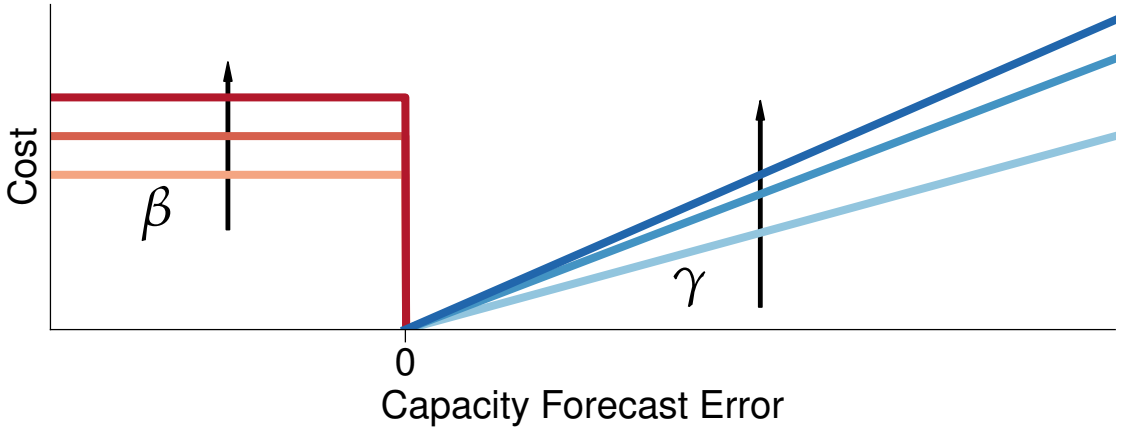


A capacity forecasting algorithm minimizes the amount of resources needed to serve a given demand



Cost-aware orchestration- Design

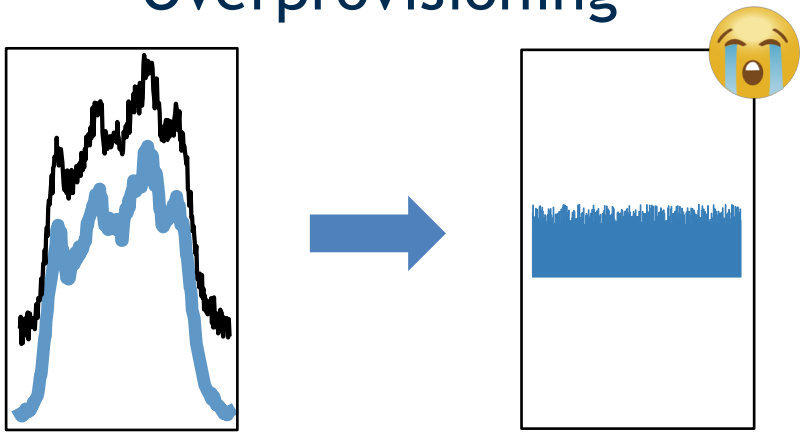
- The loss function is a **key** element in a Deep Learning architecture
  - Measures the error between output and real sample
  - Error values utilized to minimize future errors



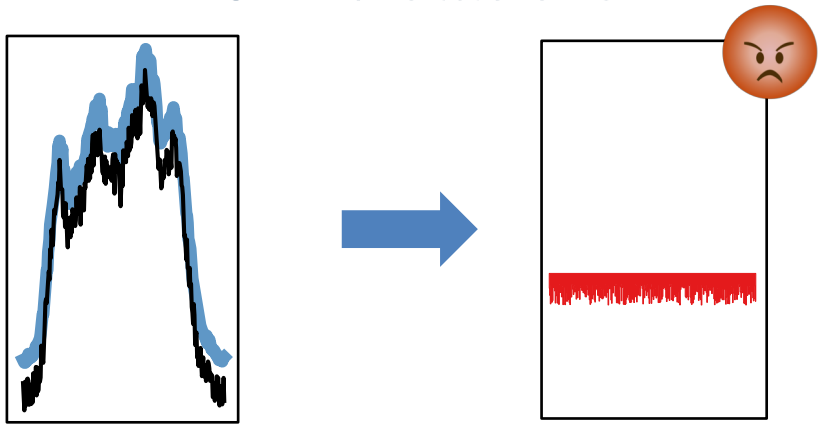
Operator Monetary Cost (OMC)

$$\alpha\text{-OMC}(x) = \begin{cases} \beta & \text{if } x \leq 0 \\ \gamma \cdot x & \text{if } x > 0. \end{cases}$$

Overprovisioning

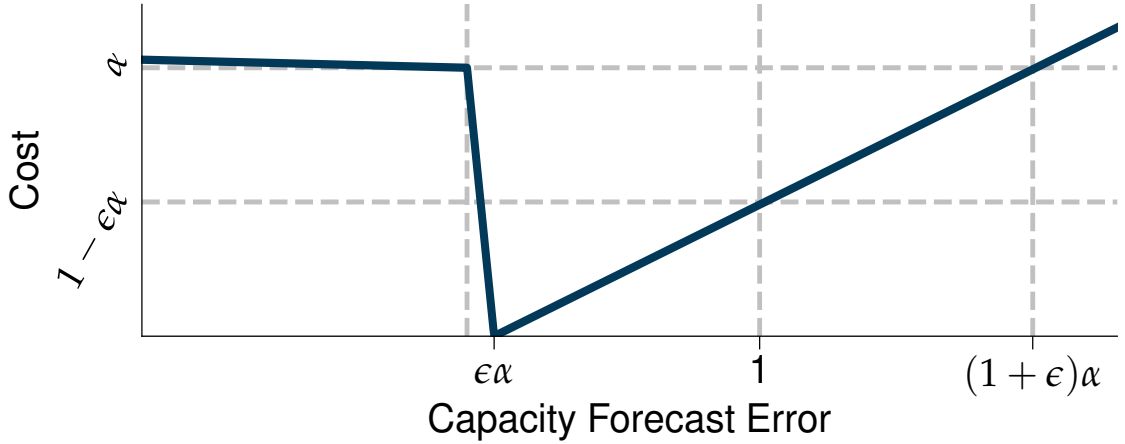


SLA Violations



Cost-aware orchestration - Implementation

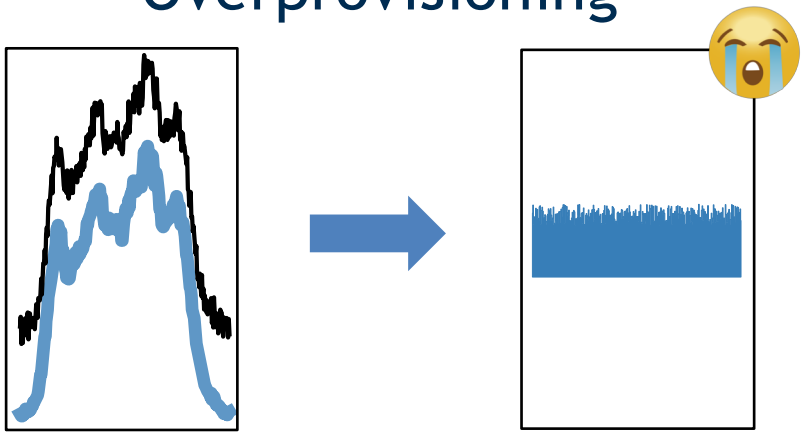
- The loss function is a **key** element in a Deep Learning architecture
  - Measures the error between output and real sample
  - Error values utilized to minimize future errors



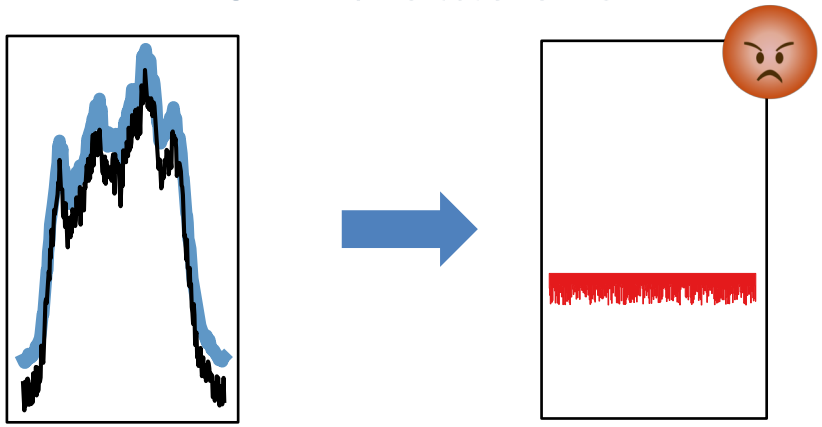
Operator Monetary Cost (OMC)

$$\alpha\text{-OMC}(x) = \begin{cases} \alpha - \epsilon \cdot x & \text{if } x \leq 0 \\ \alpha - \frac{1}{\epsilon}x & \text{if } 0 < x \leq \epsilon\alpha \\ x - \epsilon\alpha & \text{if } x > \epsilon\alpha. \end{cases}$$

Overprovisioning



SLA Violations



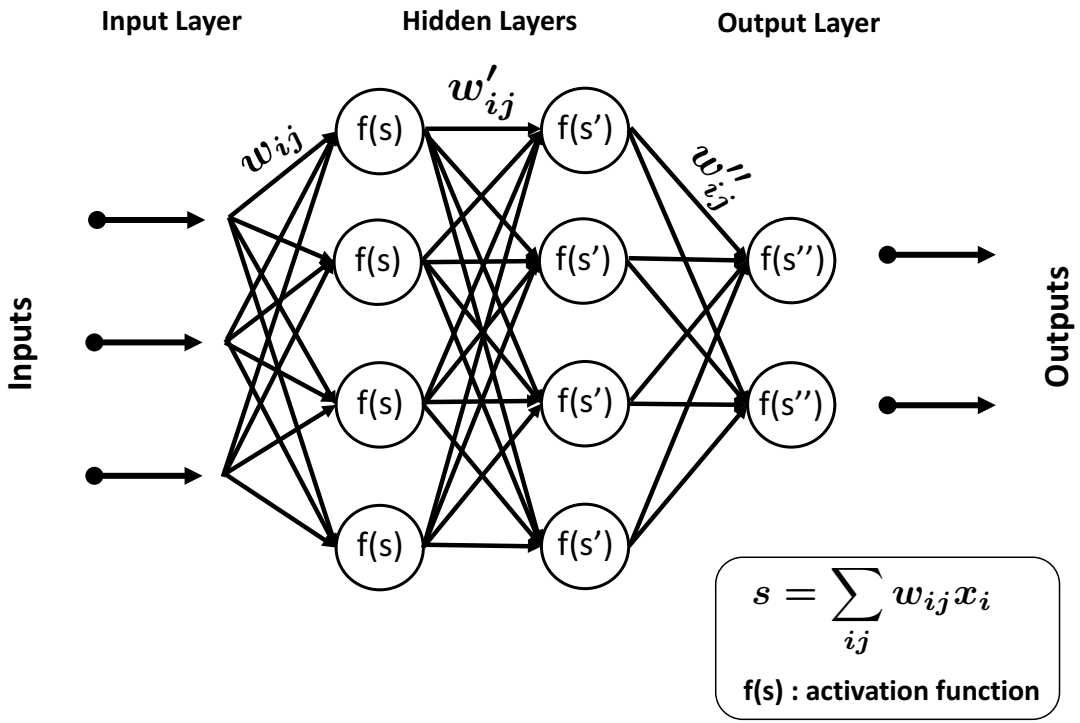
Case study

- Real-world **measurement data** from a major mobile network operator
  - Single datacenter (470 4G eNodeBs)
  - Orchestration occurs over 5-minutes interval

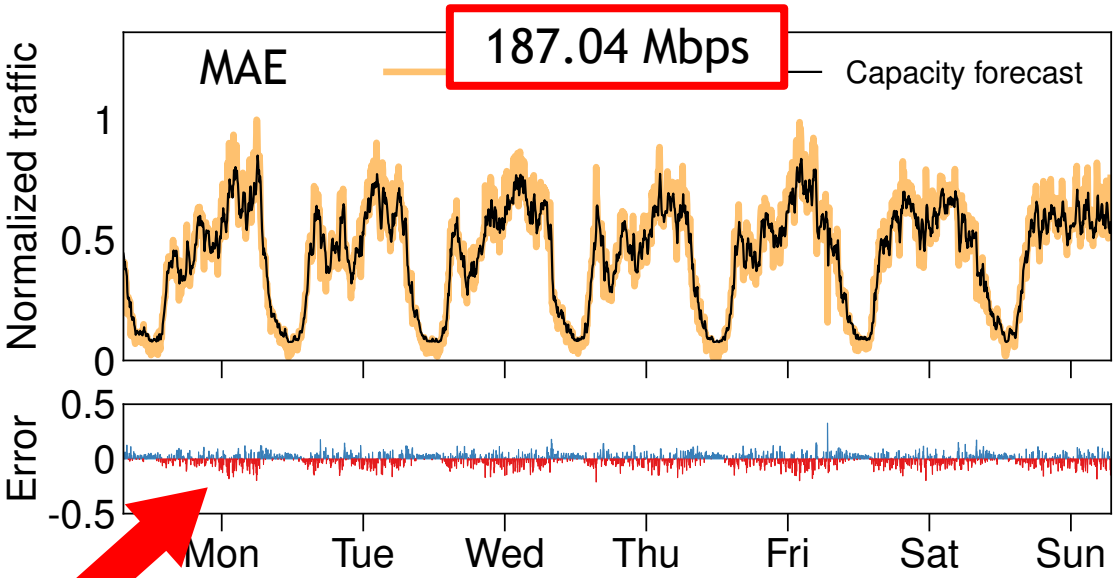
YouTube

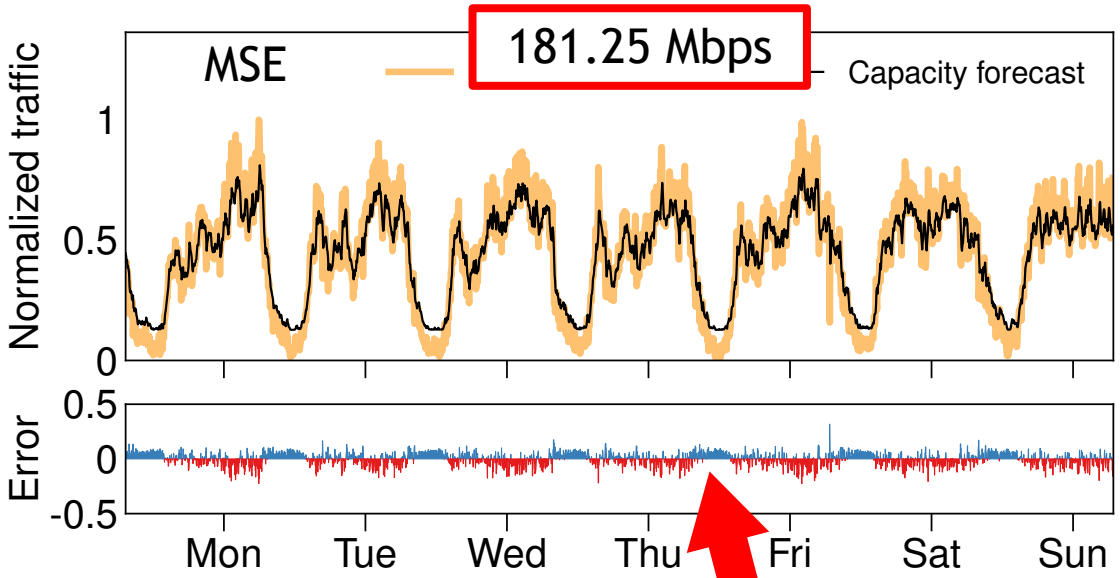
Neural Network Architecture

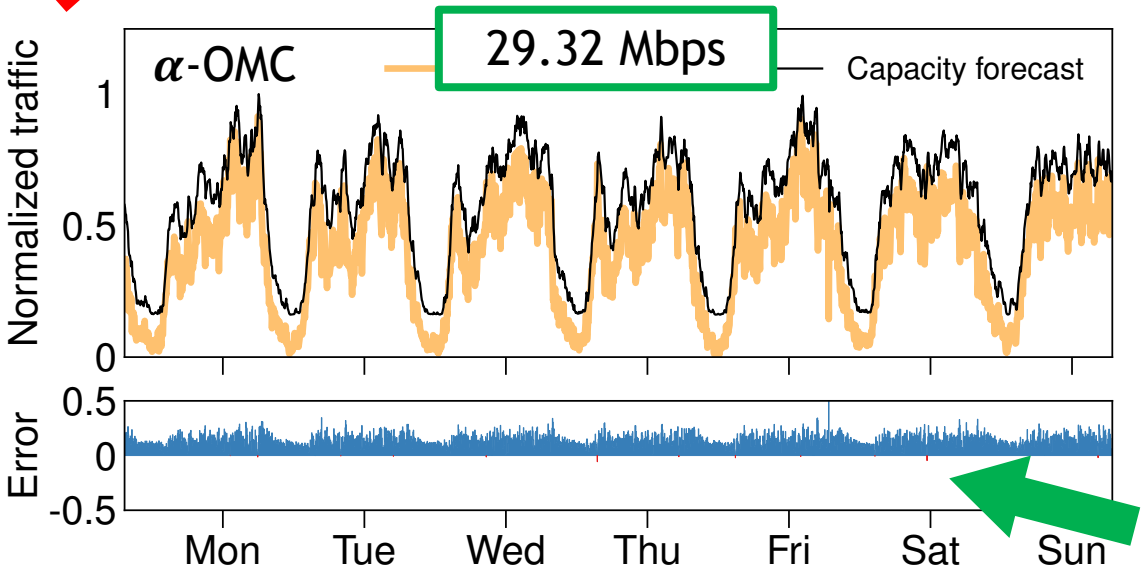
- Five different fully-connected layers architectures
  - Variable number of hidden layers (from 2 to 20)
  - 16 neurons per layer employing ReLU
- Trained with Adam optimizer



Forecast comparison







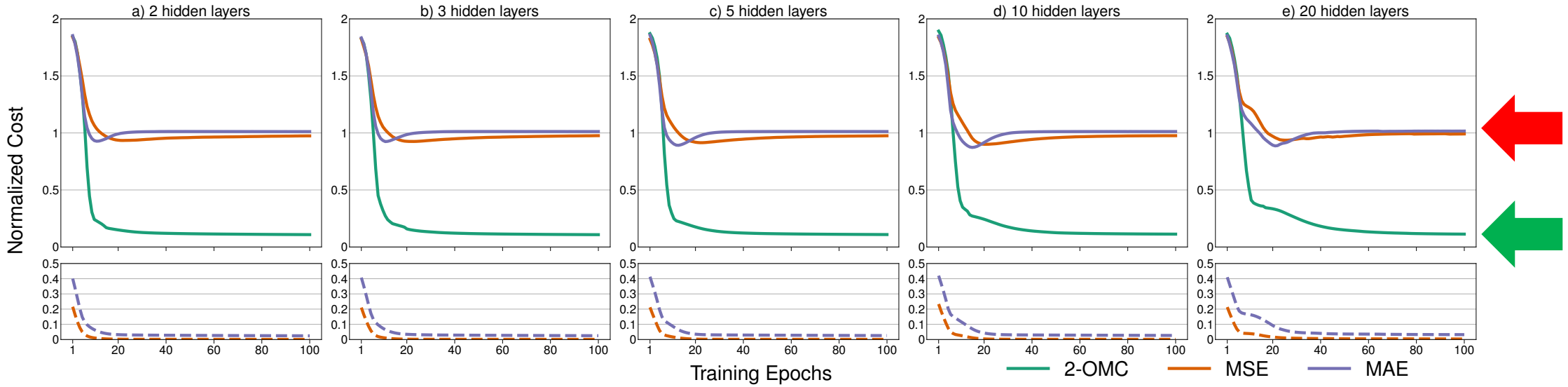
Accurate forecast for all cases

Only cost-aware loss minimize penalties

MAE and MSE result in +500% total cost

Cost-minimization - 1

- Loss functions behavior over learning time



- MAE and MSE converges to a fixed fee

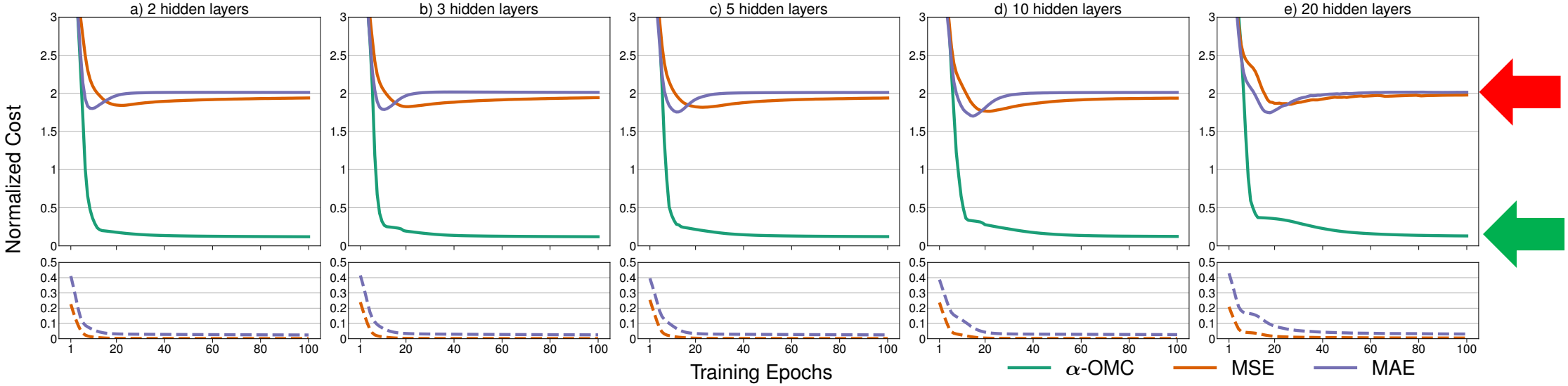
- α-OMC loss function minimizes the operator's cost

Cost-minimization - 2

- Loss functions behavior over learning time

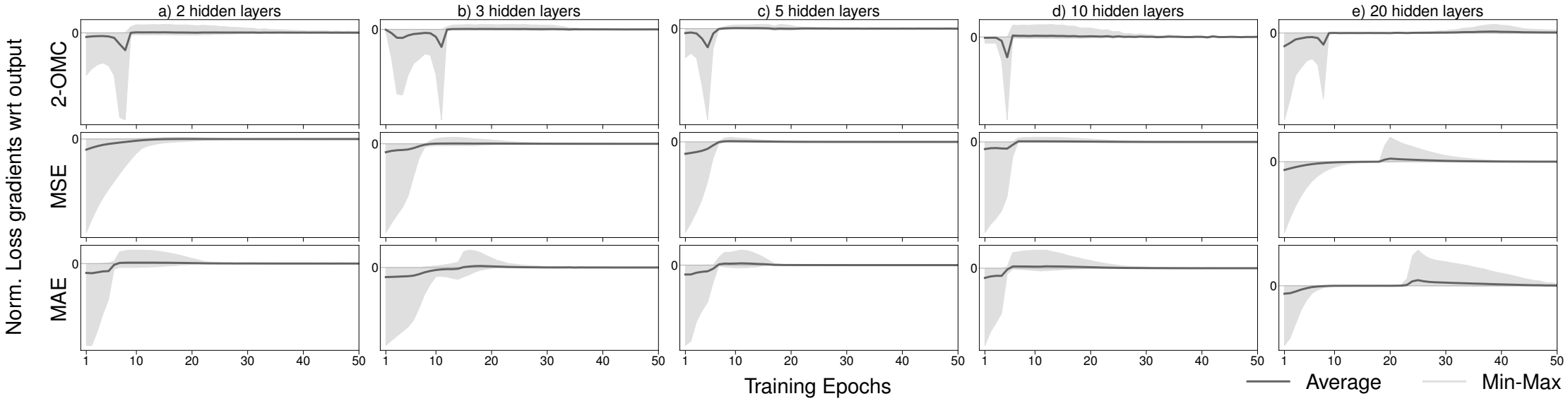
- MAE and MSE converges to a fixed fee
- The fee depends by α

- α-OMC loss function minimizes the operator's cost



Gradient behavior

- Loss functions gradients wrt last layer



- All gradients converge to 0
- Minimum (local or global) point in the loss function reached
- Convergence reached after around 50 epochs

Conclusions

- 5G mobile networks requires ad-hoc AI integration
- α-OMC represents a very first cost-aware loss function
- It solves the mobile network resource orchestration problem
- Effective in meeting real network requirements compared to SoA loss functions
- Next steps: DeepCog…

Thanks!