# NMLRG #3 meeting in Athens with EuCNC 2016

# "Mobile network state characterization and prediction"

P.Demestichas [(1)], S. Vassaki[(2)],
A.Georgakopoulos[(2)]

(1) University of Piraeus
(2) Incelligent, www.incelligent.net

June 2016

# Outline

- Service classification in 5G networks
  - Motivation/Objectives
  - Considered approach using supervised ML techniques
- QoS provision and capacity expansion in 5G networks
  - Extended Dynamic Spectrum Access (DSA)
  - Predictive RRM in environments with high-mobility
- Mobile network state characterization & prediction
  - Motivation/Objectives
  - Considered approach using unsupervised & supervised ML techniques
  - Results
- Conclusions & Next steps

# Service Classification in 5G Networks* – Motivation & Objectives

- **Motivation**
  - Existence of diverse vertical/services with different requirements in terms of QoS & capacity:
    - Mobile Broadband (MBB)
    - Massive Machine Type Communications (MTC)
    - Mission Critical Communications (MCC)
    - Broadcast/Multicast Services (BMS)
    - Vehicular to X (V2X)
  - 5G system management → meet the requirements resulting from a large variety of services to be provided simultaneously optimizing the network in order to be resource and energy efficient
  - Prioritization of services and efficient allocation of resources → need for automated service classification schemes

- **Our approach**: use of supervised ML techniques (classification)

- **Goal**: Accurate identification of services to promote an efficient network tuning (optimal assignment of resources to satisfy the diverse QoS requirements)

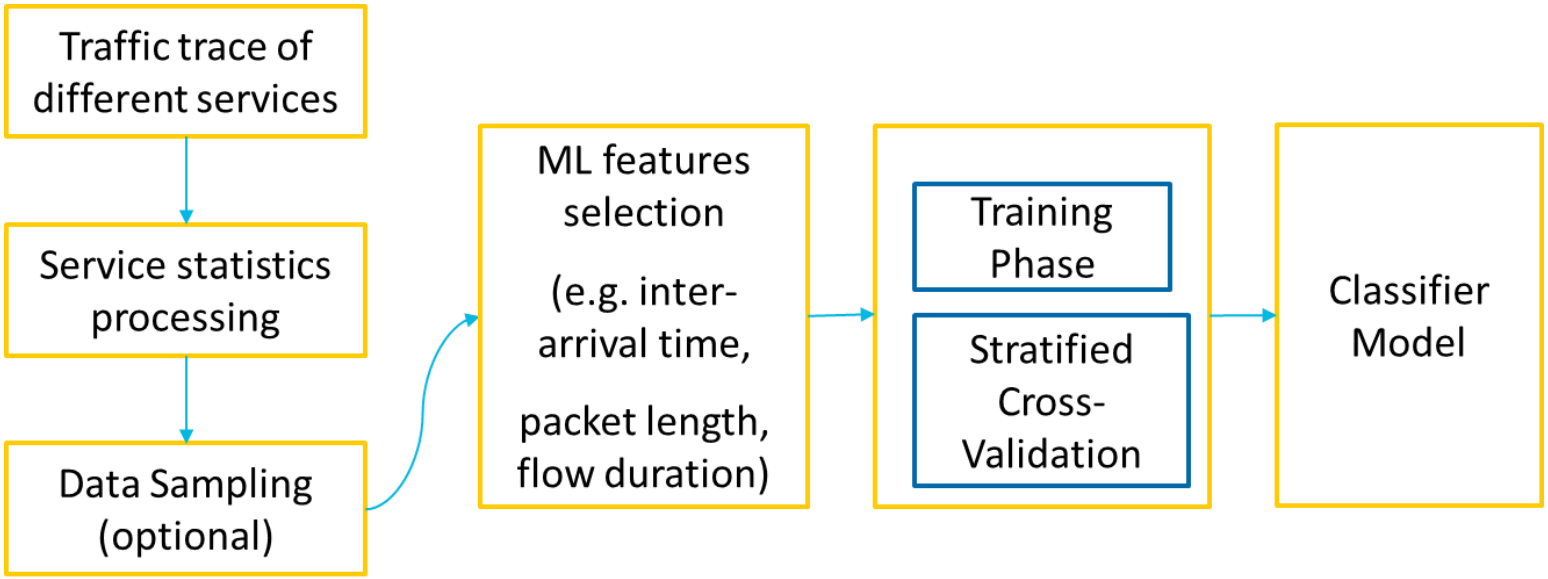
*[Investigated under the framework of FANTASTIC-5G project, H2020 G.A.671660, http://fantastic5g.eu/]

# Service Classification in 5G Networks – ML approach

- MBB → diverse services (file downloading, streaming) usually larger packets
- MMC → periodic communication (inter-arrival time), small packet size
- MCC → usually small packets (except P2P communications)
- BMS → larger packets, multicast/broadcast communication (not individual destination)
- V2X (V2V or V2I) → high speed of nodes & combination with 4 others services

| Service / Parameter | MBB (Video streaming) | MMC | MCC | BMS | V2X |
|---|---|---|---|---|---|
| **Packet length** | Usually large | Small | Small | Medium | Depends on other characteristics |
| **Statistics of Packet length (e.g. std)** | Medium | Very small | Very small | Medium-Large | Depends on other characteristics |
| **Packet inter-arrival time** | Non periodic | Periodic | Non periodic (burst effect) | Non periodic | Usually non periodic |
| **Statistics of Packet Inter-arrival time** | Medium-Large | Very small | Large | Medium | Medium |
| **Flow Direction** | DL: large packets UL:small packets | UL | UL | DL | UL/DL |
| **Flow length** | Large | Small | Small | Medium | Small-Medium |
| **Statistics of flow length (std)** | Small-Medium | Small | Small | Medium | Medium |
| **Mobility** | Average | Low | Low | Low-Average | High |

# Service Classification in 5G Networks – ML approach




## Classification

- Use of predefined classes of training instances
- 3 phases: training, cross-validation, application of classifier
- Goal: from the training dataset , find a function *f(x)* of the input features that best predicts the outcome of the output class *y* for any new unseen values of *x*
- Algorithms for investigation : Decision Trees, Naïve Bayes classification algorithms, Support Vector Machine (SVM), Random Forest

# Service Classification in 5G Networks – ML approach

| Service \ Classification Result | MMC | Other services |
|---|---|---|
| MMC | TP | FN |
| Other services | FP | TN |

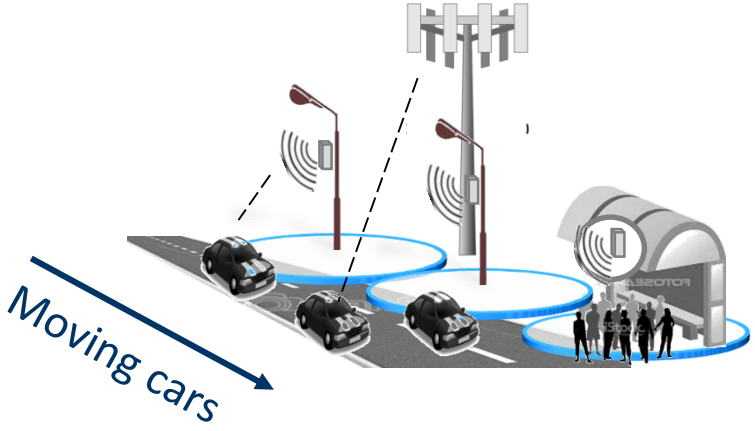
**FN**: % of members of class MMC incorrectly classified as not belonging to this class
**FP**: % of members of class MMC incorrectly classified as belonging to this class
**TP**: % of members of class MMC correctly classified as belonging to this class
**TN**: % of members of class MMC correctly classified as not belonging to this class

- Use of traditional evaluation metrics (e.g. accuracy, precision, recall)
- Analysis of the tradeoff between metrics (ROC curve)
- Optimization of metrics depending on the service (e.g. high values of Recall for MCC services)
- Definition of customized evaluation metric depending on the service

# QoS provision and capacity expansions*- Extended DSA/ RRM

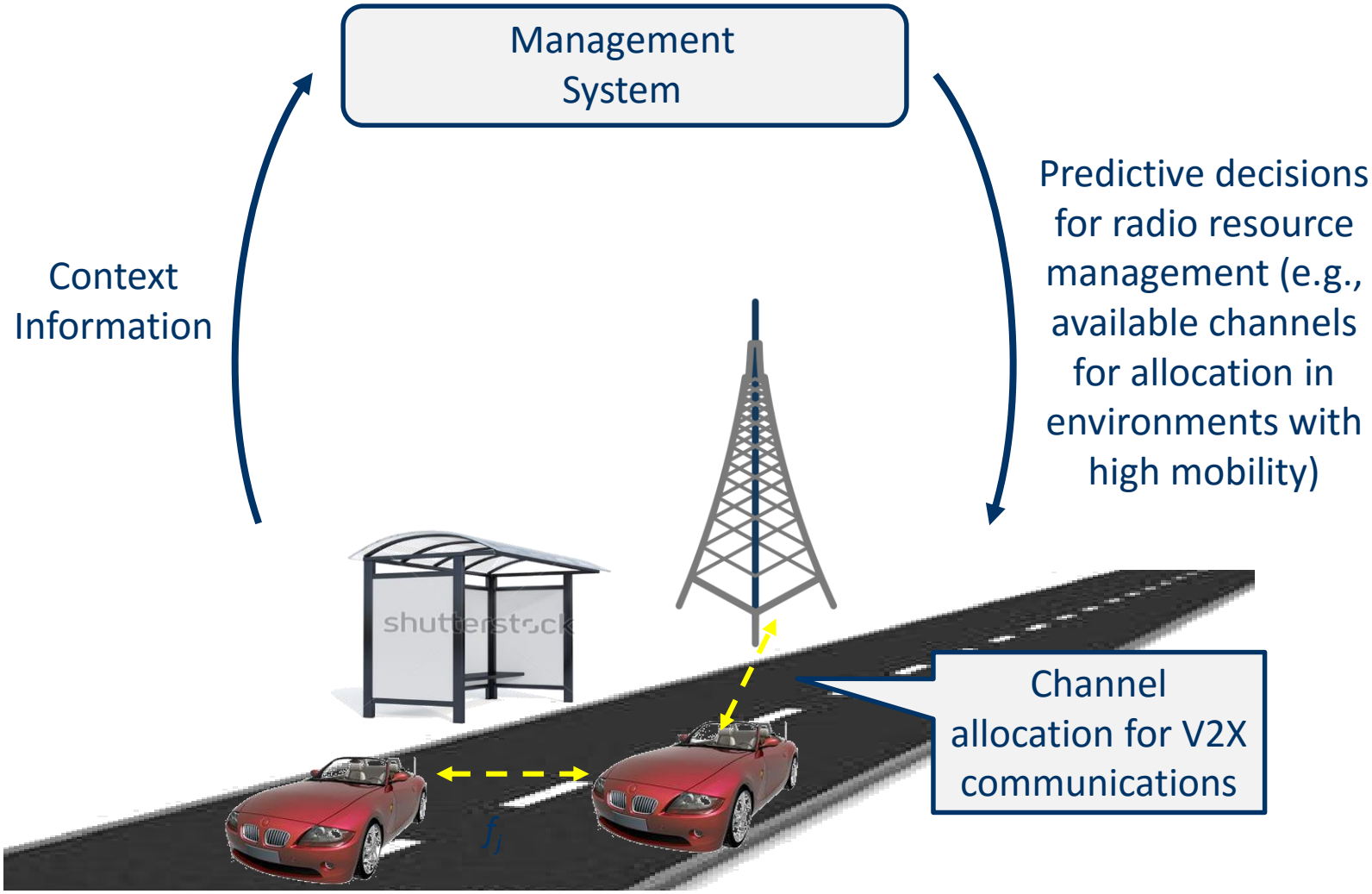
**Extensions to Dynamic Spectrum Access and RRM**

- Machine learning and prediction based solution to a complex problem
- Involving 5G services and KPIs
- Leveraging on various licensing schemes, allocation possibilities, wide range of spectrum
- Handling a wide range of mobility cases
- Leading to automated and robust solutions
- Functionality partitioned between MAC and management layers




*[Investigated under the framework of SPEED-5G project, H2020 G.A.: 671705, https://speed-5g.eu/]

# QoS provision and capacity expansions - Predictive RRM in environments with high-mobility



# Mobile network state characterization & prediction – Motivation & Objectives

- **Motivation**
  - Diverse and complex actions (addition/removal of TRXs, transition from 2G→3G→4G features etc) take place in a real-world mobile network
  - Online optimization of network performance → automated analysis of each action's impact to the network KPIs (customized to the specific network characteristics)

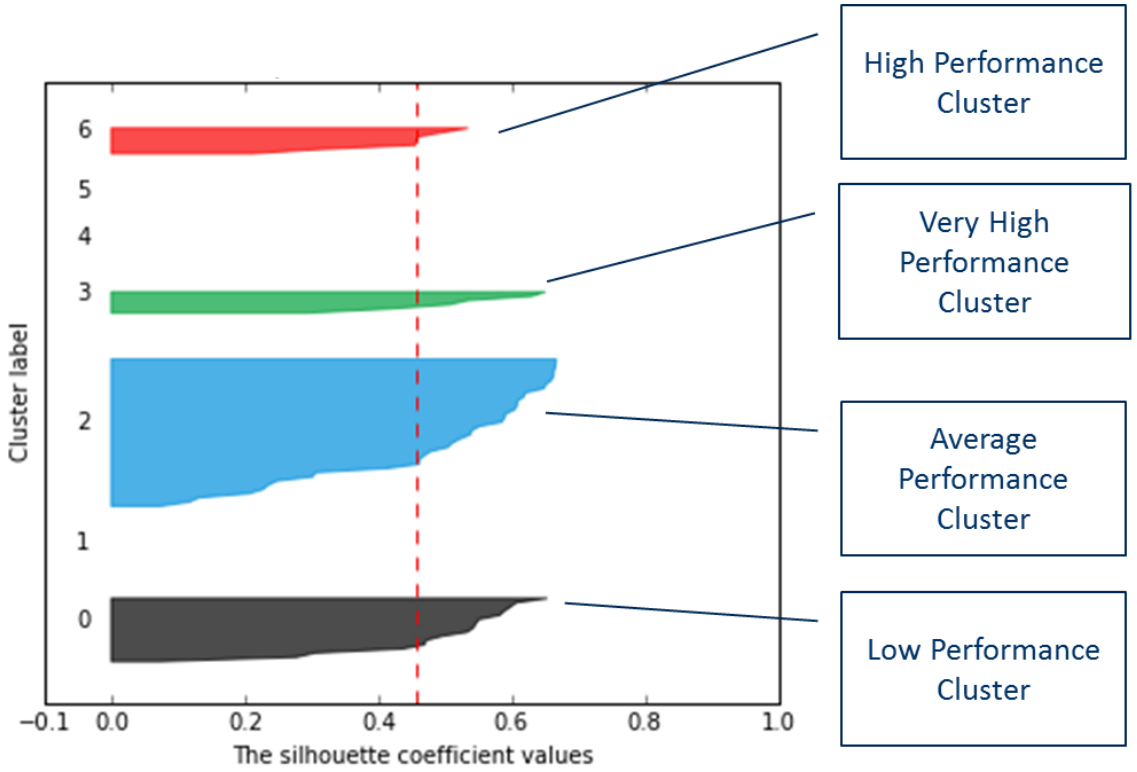
- **Our approach:**
  - Impact analysis of resource allocation actions using unsupervised ML techniques (clustering approach)
  - Prediction of network traffic/quality metrics using supervised ML techniques

- **Objectives**:
  - Identification of resource allocation actions that result in ameliorated/ deteriorated network performance
  - Prediction of future network KPIs considering that a specific resource allocation action will take place

# Mobile network state characterization & prediction – ML approach

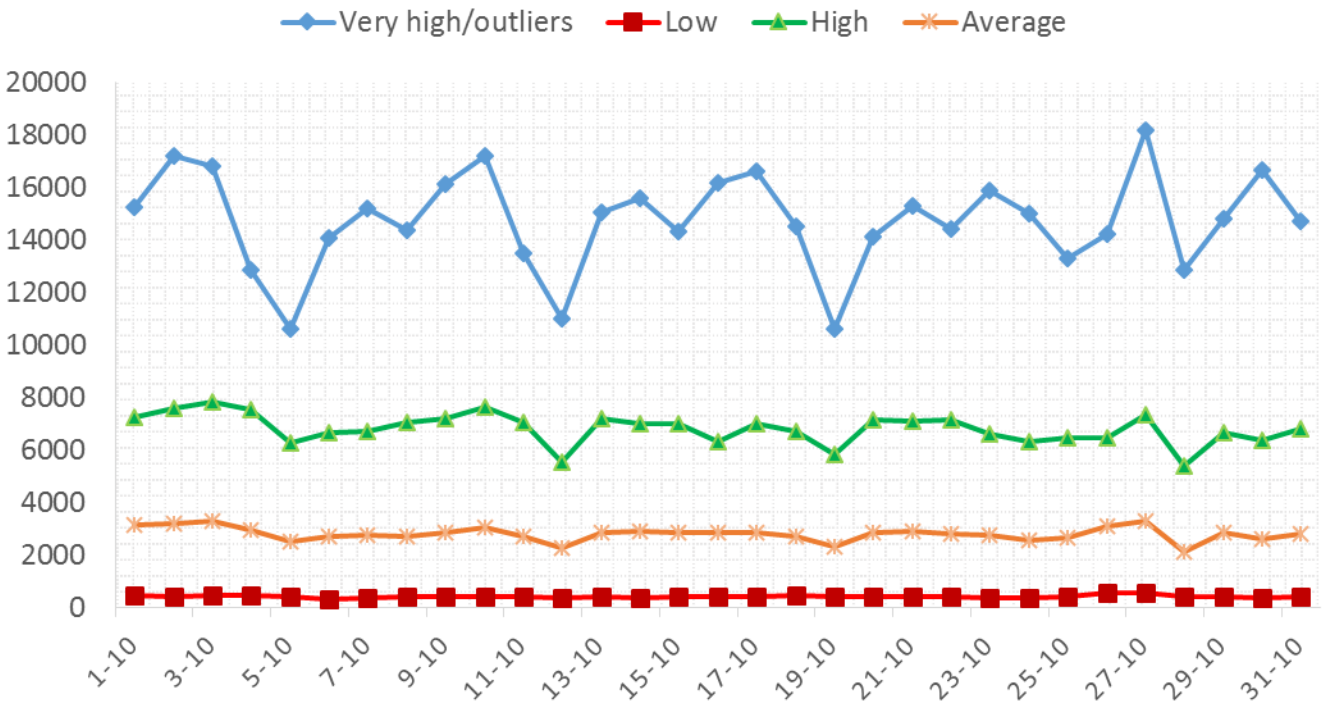
- Impact Analysis of resource allocation actions using clustering mechanisms:
  - Input of ML mechanism: network traffic/quality data of cells that affected by these actions
  - ML mechanism: Clustering (k-Means)
  - Output of ML mechanism: groups of cells where the cells in the same group (called a **cluster**) are more similar to each other than to those in other groups

*x*-axis (silhouette coefficient values) : separation distance between the resulting clusters; how unsimilar each cell in one cluster is to cells in the neighboring clusters



# Mobile network state characterization & prediction – ML approach

- Impact Analysis of resource allocation actions using clustering mechanisms:
  - Indicative clustering results (centroids representation) for traffic data of cells in a specific region
  - Input data: Voice traffic data during one month period
  - Ouput data: 4 clusters of cells (Low/Average/High/Very High Performance)



# Mobile network state characterization & prediction – ML approach

- Prediction of network traffic/quality metrics using supervised ML techniques
  - Input of ML mechanism: network traffic/quality data of cells that affected by these actions
  - ML mechanism: Time series prediction mechanisms (SVM, Neural Networks etc)
  - Output of ML mechanism: predicted future values of traffic/quality metrics for specific cells using past traffic/quality data
- Next steps:
  - Use of accurate evaluation metrics for time series prediction
  - Analysis of the tradeoff between metrics depending on the KPIs

# Conclusion - Next steps

- Development of automation mechanisms based on machine learning for:
  - Service Classification in 5G networks
  - QoS provision in 5G networks
  - Mobile network state characterization

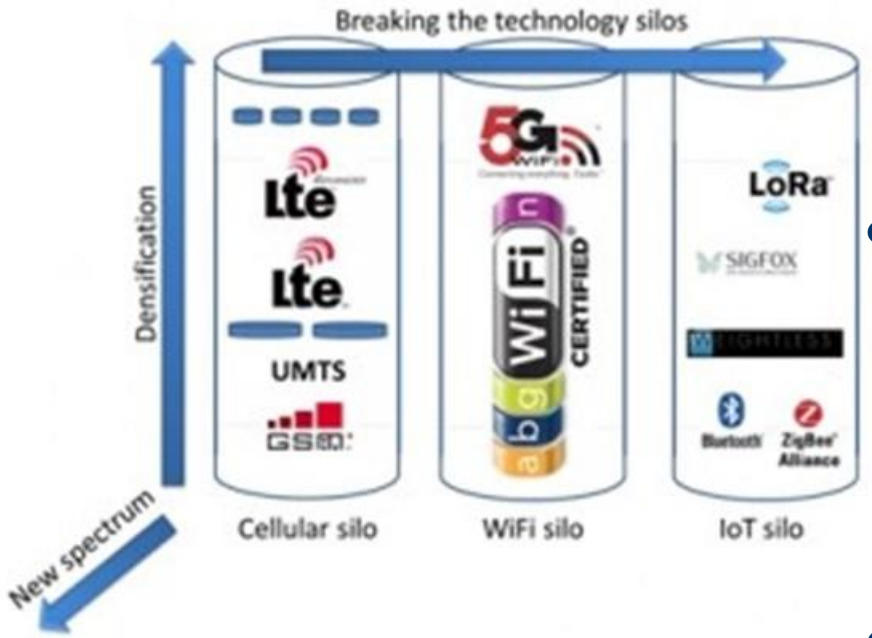
- Evaluation of service classification techniques for 5G networks
  - Definition/Selection of evaluation metrics
- Evaluation of predictive mechanisms in a high mobility scenario
  - Impact analysis of high mobility characteristics in prediction model
- Evaluation of predictive mechanisms for real-world mobile network scenario
  - Selection of adequate evaluation metrics

Thank You!

For details you can visit:
http://tns.ds.unipi.gr
http://incelligent.net
http://wings-ict-solutions.eu

# Backup Slides

# QoS provision and capacity expansion: Speed-5G




- SPEED-5G intends to break spectrum and technology silos for optimal service provisioning and quality of experience
- Challenge on how to break the technological silos in a more flexible way in the longer term by exploiting and improving advanced flexible wireless technologies
- Improving autonomous management of small cells in dense scenarios

# Service Classification in 5G Networks: FANTASTIC-5G

- FANTASTIC-5G aims to develop a new multi-service Air Interface (AI) for below 6 GHz through a modular design
- Key characteristics of the new interface:
  - flexibility, scalability, versatility, efficiency and future-proofness
- Development of the technical AI components and integration an overall AI framework where adaptation to various sources of heterogeneity will be accomplished