ITU KALEIDOSCOPE
SANTA FE 2018

Machine learning for a 5G future

WRAP-UP SESSION

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26-28 November
Santa Fe, Argentina

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SESSION 1

S1.1 (Invited) A Machine Learning Management Model for QoE Enhancement in Next Generation Wireless Ecosystems
Eva Ibarrola, University of the Basque Country (UPV/EHU),

S1.2 Unsupervised Learning for Detection of Leakage from the HFC Network – **Emilia Gibellini**, Telecom Argentina

S1.3 Double Sarsa Based Machine Learning to Improve Quality of Video Streaming over HTTP Through Wireless Networks
Dhananjay Kumar, Anna University

Session 1, Machine Learning in Telecommunication Networks – I
Ved P. Kafle, National Institute of Information and Communications Technology, Japan

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Highlights from Paper S1.1
"A Machine Learning Management Model for QoE Enhancement in Next Generation Wireless Ecosystems"

- New QoS management models considered for next-generation wireless ecosystems
- Usefulness of machine learning technique described
  - To detect QoS anomalies
  - To identify KQI
  - To infer correlation models (NP/QoE)…
- The study gives good ideas about the capabilities of machine learning techniques to enhance the QoE in next generation wireless scenarios

Highlights from Paper S1.2
"Unsupervised Learning for Detection of Leakage from the HFC Network"

- Cable operators use Full-Band Capture (FBC) to look for impairments.
  - One in particular, ingress, is likely to happen along with leakage, which damages the radioelectric spectrum.
- They are looking for a solution based on ML to improve proactive detection.
- Predictions help field service teams fix the root cause of leakage & ingress.

Highlights from Paper S1.3

"Double Sarsa Based Machine Learning to Improve Quality of Video Streaming over HTTP Through Wireless Networks"

- A reinforcement (Double Sarsa) based machine learning method is proposed to improve the quality of live video streaming
- A client-server model considered, where clients estimate quality of experience and feedback to servers for quality adaptation of the stream.
- ITU-T Rec. P.1203 video quality estimation model used in algorithm, J.247 and P.1203 are used to govern video streaming parameters during experimentation
  - Implemented on the top of HTTP in a typical internet environment through 4G wireless.
  - Results validated using standard video quality measurement metrics.

Conclusions/Recommendations

- Three papers presented very interesting ideas (with validation) on the usefulness of machine learning in improving quality service (QoS) or quality of experience (QoE) of communication systems.

- Paper S1.1 and S1.3 have considered adding machine learning techniques to already established ITU standards. The research contribution can be useful in the standardization of machine learning approaches in 5G networks (ITU-T SG12/SG13, ITU-R SG5/SG6).

- Paper S1.2 explores the potential of machine learning in the process of fault detection and recovery in hybrid fiber and coaxial networks. The contribution can be brought to ITU-T SG12.

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SESSION 2

S2.1 Self-Healing and Resilience in Future 5G Cognitive Autonomous Networks
Stephen S. Mwanje, Nokia Bell Labs, Germany

S2.2 AI as a Microservice (AIMS) over 5G Networks
Tai-Won Um, Chosun University, Korea

S2.3 Multifractal Modeling of the Radio Electric Spectrum Applied in Cognitive Radio Networks
Luis Tuberquia David and **Cesar Hernández**, Universidad Distrital Francisco José de Caldas, Colombia

S2.4 Towards Cognitive Autonomous Network in 5G
Stephen S. Mwanje, Nokia Bell Labs, Germany

Session 2, AI and 5G
Dhananjay Kumar, Anna University, India

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Highlights from Paper 1
"Self-Healing and Resilience in Future 5G Cognitive Autonomous Networks"

- In 5G, mobile networks are becoming ever more complex and dynamic while at the same time there are new use cases requiring ultra-high reliability
  - Simple robustness and redundancy is no longer enough, we need resilient systems that can adapt even to unforeseen problems and changes
- One way to increase the resilience of a network is by using anomaly detection and diagnosis methods
  - Able to detect also unanticipated problems
  - An anomaly detection based self-healing function for Radio Access Network with focus on cross-domain and management area holism and augmented diagnosis methods

Highlights from Paper 2
"AI as a Microservice (AIMS) over 5G Networks"

- As data-driven decision-making services are being infused into Internet of Things (IoT) applications, Artificial Intelligence (AI) algorithms are being deployed as monolithic application services.
- For latency sensitive IoT applications, it is inefficient to transmit data to the Cloud data centers for storage and AI based processing.
- This article proposes 5G integrated architecture for intelligent IoT based on the concepts of AI as a microservice (AIMS).
  - AIMS can support the design and development of AI microservices, which can be deployed on federated and integrated 5G networks slices to provide autonomous units of intelligence at the Edge of Things.

Highlights from Paper 3
"Multifractal Modeling of the Radio Electric Spectrum Applied in Cognitive Radio Networks"

- Methodologies are defined to perform measurements in the radio spectrum of Bogota.
- Methods has been proposed for **adjusting** traffic as multifractal traces
- The goal is to establish a tool that can estimate traffic with similar characteristics to those found in the radio spectrum of Bogotá.
- The data collected from the radio spectrum of Bogotá reveals that Wi-Fi traffic has a multifractal behavior.

Highlights from Paper 4
"Towards Cognitive Autonomous Network in 5G"

- Network management complexity (e.g. mult-RAT/layer/...) requires cognition
- Cognition inspired by humans implies a Perception-Reasoning pipeline that:
  - conceptualizes sensory data and contextualizes it for perception,
  - Relates it to existing data for knowledge and then makes inferences therefrom
- A taxonomy of cognitive automation derives the levels of automation and the transition from manual to cognitive autonomous networks
- The CAN architecture presents core modules i.e. control, coordination, state modelling, objective management and the use-case-specific apps.
- An example shows results of supervised learning estimating mobility performance for different states and control parameter values.

Conclusions/Recommendations

- Radio Access Network anomaly detection, diagnosis, and self-healing across domains and management areas in 5G future mobile networks is a requirement.
- AI can be used as microservices at the Edge of Things considering integrated infrastructure spanning the ROOF, Fog and Cloud computing platforms.
- Multifractal modeling of the radio electric spectrum applied in cognitive radio networks helps in studying behavior of spectrum in estimating traffic.
- Learning methods can automate network management (i) to learn the best configurations for specific states, and (ii) the underlying network response which can then be used to predict response in unknown states.

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SESSION 3

S3.1 Invited paper - Machine Learning Opportunities in Cloud Computing Data Center Management for 5G Services
Benjamín Barán, National University of the East, Paraguay

S3.2 Consideration on Automation of 5G Network Slicing with Machine Learning
Ved P. Kafle, National Institute of Information and Communications Technology (NICT), Japan

Session 3, Machine Learning in Telecommunication Networks – II
Mostafa Hashem Sherif, Consultant, USA; Kaleidoscope Steering Committee Member and TPC Chair

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Highlights from Paper 1
"Machine Learning Opportunities in Cloud Computing Data Center Management for 5G Services" (Invited Paper) (1/3)

- In cloud computing, datacenters, Machine Learning (ML) techniques can be used to define the optimum placement of requested virtual machines on to an available physical machine (the virtual machine placement problem, VPMr).
- The solution of the optimization scheme is done in two phases:
  - The placement is done first with incremental online calculations
  - Under some conditions, the placement is recalculated offline and the machine placement reconfigured
  - The conditions are called "virtual machine placement reconfiguration VMPr trigger"
- VPMr triggering can be done with:
  - On a periodic basis, for example, every 10 minutes
  - Based on a per-defined threshold of CPU utilization
  - Using predictions based on statistical techniques such as exponential smoothing
  - Machine learning techniques

Highlights from Paper 1
"Machine Learning Opportunities in Cloud Computing Data Center Management for 5G Services" (2/3)

- Characteristics of Infrastructure as a Service model of Cloud Computing:
  - On-Demand self-service (dynamic)
  - Rapid elasticity (dynamic)
- Most relevant dynamic parameters:
  - Resource capacities of VMs
  - Number of VMs
  - Resource utilization of VMs (overbooking)
- Areas of studies for 5G networks:
  - Which machine learning techniques should be used to predict network routing reconfiguration (NNR)
  - Which machine learning techniques should be used for regression (supervised learning) and clustering the virtual machines (unsupervised learning)

Highlights from Paper 1
"Machine Learning Opportunities in Cloud Computing Data Center Management for 5G Services" (3/3)

- Research questions:
  - Which ML techniques could be considered more appropriate for VMPr Triggering methods?
  - How important is the prediction of the actual to trigger time for the VMPr phase in VMP problems?
  - In addition to the prediction of the objective functions, what other parameters could be evaluated for VMPr Triggering methods?
  - Which machine learning techniques should be used to predict network routing reconfiguration (NNR)
  - Which machine learning techniques should be used for regression (supervised learning) and clustering the virtual machines (unsupervised learning)
- It was remarked during the discussion that initially, 5G networks will managed with the same network management system of 3G and $G (LTE) networks

Highlights from Paper 2
"Consideration on Automation of 5G Network Slicing with Machine Learning" (1/3)

- Projected services in 5G/IMT-2020 networks have diverse requirements
- Network slicing allows creating multiple virtual networks over the same physical network to manage various service requests with different QoS requirements in 5G/IMT-2020 networks
- Machine learning can be used to reduce the time to construct the network slices
- The various network management functions typically require different machine learning techniques and strategies

Highlights from Paper 2
"Consideration on Automation of 5G Network Slicing with Machine Learning" (2/3)

- Newly formed groups of various standard development organizations and fora are working on the issue:
  - ETSI IISG ENI, February 2017
  - ISO/IEC JTC 1/SG42, October 2017
  - ITU FG-ML5G: November 2017
  - TM Forum Catalyst Project on Smart BMP (Business Project Management): Proof-of-concept projects developed collaboratively by TM Forum members.
  - Note: IETF network slicing group have not been chartered yet

Highlights from Paper 2
"Consideration on Automation of 5G Network Slicing with Machine Learning" (3/3)

- 5G network slicing scenarios and related functions requiring automation
- Machine learning techniques for network function automation improve network management in two cases:
  - Resource classification with the Support Vector Machine method
  - Resource adaption with the Reinforcement Learning method
- Standardization activities:
  - ITU-T Study Group 13
  - FGML 5G meeting in parallel in Tokyo this week will discuss some of the use cases

Conclusions/Recommendations (1/2)

- Investigate additional machine learning techniques to improve network routing configuration (NNR) in 5G/IMT-2020 Networks:
  - Which machine learning techniques should be used predicting network routing reconfiguration (NNR)
  - Which machine learning should be used for clustering virtual machines
- Coordinate standardization activities with among SDOs
- One issue that arose during the questions/answers is how network slicing affects and is affected by net-neutrality legislation. The recommendation is to organize a session on that topic in the Kaleidoscope 2019 conference by inviting lawyers, network engineers, content providers and civil societies representatives

Conclusions/Recommendations (2/2)

- Several research projects were identified regarding virtual machine placement in cloud computing
- Actual data from 5G networks will not available in Paraguay for sometime and Professor Barán would be grateful if results from early implementations could be shared
- Investigations on machine learning techniques to improve network routing configuration (NNR) in 5G/IMT-2020 networks should continue
- Coordination of standardization activities with among SDOs should be followed
- One issue that arose during the questions/answers is how network slicing affects and is affected by net-neutrality legislation. The recommendation is to organize a session on that topic in the Kaleidoscope 2019 conference by inviting lawyers, network engineers, content providers and civil societies representatives

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SESSION 4

S4.1 A Deep Reinforcement Learning Approach for Data Migration in Multi-access Edge Computing
Dario Bruneo, University of Messina, Italy

S4.2 Predicting Activities in Business Process with LSTM Recurrent Neural Networks
Jorge Roa, Universidad Tecnológica Nacional, Facultad Regional Santa Fe, Argentina

Session 4, Optimization of Data Management with Machine Learning
Joan Garcia-Haro, Technical University of Cartagena, Spain, Spain

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Highlights from Paper 1
"A Deep Reinforcement Learning Approach for Data Migration in Multi-access Edge Computing"

- Users and their applications are increasingly demanding to the cloud more resources, which might result in high latencies.
- Multi-access Edge Computing (MEC) is observed as an enabler for the 5G KPIs, such as low latency and BW efficiency; since MEC moves data and computational resources nearby the user.
- Authors propose a deep Reinforcement Learning (RL) approach to manage data migration in MEC scenarios to improve user QoS.
- Paper contributions:
  - A deep RL algorithm to manage complex MEC systems.
  - A simulation environment to test RL approaches in LTE/5G scenarios.

Highlights from Paper 2
"Predicting Activities in Business Process with LSTM Recurrent Neural Networks"

- The Long Short-Term Memory (LSTM) Recurrent Neural Networks provide an accurate prediction of sequences.
- In the Business Process Management (BPM) domain event logs can be exploited to make predictions about the execution of cases.
- The paper addresses the LSTM networks application to predict execution of cases using event logs originated from the IoT and Industry 4.0.
- A methodology to implement an LSTM neural network is also proposed.
- Test conducted on the trained LSTM network showed its capacity to predict the next activity of a business process model.

Conclusions/Recommendations

- Paper 1: Preliminary results to demonstrate the feasibility of the RL MEC approach (simplified LTE scenario, no comparison with a system using the cloud).
- Paper 2: Preliminary results (based in a data set with 255 traces) indicated that the prediction of the next activity is acceptable.
- A complete set of test (more use cases) under more realistic conditions should be conducted.
- Impact on standards should be investigated.
- ML will play an essential role in systems that produce a huge volume of data (such as 5G IoT systems), enabling for high performance smarter services, applications, and business processes.

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SESSION 5

S5.1 Smart Usage of Multiple RAT in IoT-oriented 5G Networks: A Reinforcement Learning Approach
Ruben Martínez Sandoval, Universidad Politécnica de Cartagena, Spain

S5.2 Message Collision Identification Approach Using Machine Learning
Bruno Marengo and **Juan Pablo Prina,** Universidad Tecnológica Nacional, Argentina

S5.3 Optical Flow Based Learning Approach for Abnormal Crowd Activity Detection with Motion Descriptor Map
Dhananjay Kumar, Anna University, India

Session 5, Network Applications of Machine Learning
Mariano Pablo Rubiolo, CIDISI UTN, sinc(i) FICH/UNL-CONICET, Argentina

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Highlights from Paper 1
"Smart Usage of Multiple RAT in IoT-oriented 5G Networks: A Reinforcement Learning Approach"

- **IoT nodes** deployed in **Smart Cities/Industries** may benefit **from multiple RAT** (Radio Access Technologies).
- Use **Machine Learning**t to select **the RAT** to use.
- **Reinforcement Learning** approach to address problem leads to the the RL-based policy..
- **Evolution Strategies** algorithm to evolve the ANN proposal.
- A **scenario** with **5G** and **LoRa** is studied.
- **Three** alternative **policies** (5G first, Priority-based and random) compared with the RL-based policy.
- The **superior performance of RL-based policies** for RAT selection is shown.

Highlights from Paper 2
"Message Collision Identification Approach Using Machine Learning"

- Extend terrestrial **ADS-B coverage** with **LEO satellites**.
- **Message collisions** in highly congested areas.
- Use **machine learning** techniques to **estimate collisions**.
- **Features Extraction** to derive **relevant information** from input data and make algorithms more efficient.
- **K-Nearest Neighbors and Support Vector Machines** are used to **classify** whether if it is possible to decode or not the ADS-B message.
- **Error probability was similarly low** for both methods, but kNN has a slower classification time than SVM.
- It could **contribute to** improve International Recommendations and Standards.

Highlights from Paper 3
"Optical Flow Based Learning Approach for Abnormal Crowd Activity Detection with Motion Descriptor Map"

- **Intelligent visual surveillance** (IVS) **for identification of** specific objects, behaviors or attributes in video signals: **abnormal human activities in a crowded scene**.
- **Training phase**: normal patterns are clustered. **Detection phase**: if the pattern differs significantly from the normal ones learned, they are considered as abnormal.
- Four major **modules** in the system (**ITU recommendations**): optical flow of blocks computation, motion descriptor computation, motion descriptor pattern clustering, and nearest neighbor search.
- Two **public datasets** were used validate the effectiveness of the method and a **custom made dataset (local environment)** to test the proposal with high performance.

Conclusions/Recommendations

- ITU recommendations were considered in the most of the works.
- All papers applied efficiently machine learning methods for solving their problems.
- Hyperparameters of the ML methods should be optimized to obtain the best model configuration.
- Authors should use more efficiently clustering and classification models for improving their proposal.

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SANTA FE 2018
Machine learning for a 5G future

SESSION 6

S6.1 A Gendered Perspective on Artificial Intelligence
Smriti Parsheera, National Institute of Public Finance and Policy; Indian Institute of Technology, New Delhi, India

S6.2 Ethical Framework for Machine Learning
Charru Malhotra, Indian Institute of Public Administration, India

S6.3 Undeclared Constructions: A Government's Support Deep Learning Solution for Automatic Change Detection
Pamela Ferrari Lezaun and **Gustavo Olivieri**,UTN, Argentina

Session 6, Social, Legal and Ethical Aspects in Machine Learning
Eva Ibarrola, University of the Basque Country, Spain

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Highlights from Paper 1
"A Gendered Perspective on Artificial Intelligence"

- Gender plays a key role in AI's knowledge-making process. It influences:
  - Who does the research
  - What research agendas are set
  - The process through which the research goals are reached.
- We need systematic interventions to re-envision AI from a gendered perspective
  - To embed "fairness by design" in AI ethics frameworks
  - To invest in R&D in fairness enhancing tools and opening up of that research
  - To address the underlying data sets
- Need similar debates on other dimensions like education, race, class, religion and nationality and the intersectionality of these factors.

Highlights from Paper 2
"Ethical Framework for Machine Learning"

- Proposed Ethical Framework
  - Combine Emotional Quotient (EQ) and Spiritual Quotient(SQ) with Intelligence Quotient (IQ) in ML algorithms
  - Diff Machine Learners : Mechanical , Cognitive, Ethical Learner , Ethical Leader
- Implementation Strategy – National, Organizational, Design-Level
- Way Forward
  - *Formulate*: International Guidelines
  - *Intervene* :National level standards, flexi-regulatory f/ws, Standards, Templates
  - *Monitor & Control*: National authority to monitor ethical indices & Quality of Values
  - *Collaborate*: Multi-disciplinary teams, Associations of think tanks, academia, industry, ethic-advocates, ethics-activities , 'East-meets-West'

Highlights from Paper 3
"Undeclared Constructions: A Government's Support Deep Learning Solution for Automatic Change Detection"

- Many constructions are not being declared causing problems
  - A loss in tax revenue, ecological damage, buildings collapse…
- Proposed solution
  - System that automates the detection of problematic situations with the use of Deep Learning algorithms (processing satellite images)
- Resulting solution
  - A combination between already existent technologies and the development of an architecture to achieve changes detection.
- Future improvements
  - 3D detection, drone captured input images and a cloud-based platform to provide services are being considered.

Conclusions/Recommendations

- Artificial Intelligence (AI) will rapidly change human's life and habits
- We need to introduce new gender and ethical frameworks to resolve many of the dilemmas that AI and ML will bring
- To face the implications of AI and ML, more contributions are invited in next Kaleidoscope conferences to move from general principles to specific solutions, policies, resources, procedures and standards
- Work on both social and technological aspects has to planned for the long term, i.e., not to give up easily.