A review of network slicing in 5G and beyond: Intelligent approaches and challenges
Thank you

Ghazal Rahmanian\(^1\)
Hadi Shahriar Shahhoseini\(^1\)
AmirHossein Jafari Pozveh\(^{1,2}\)
\(^1\)Iran University of Science and Technology
\(^2\)Iran Mobile Communications Company (MCI)

Session 6: Machine learning for next generation wireless network

Paper S6.2: A review of network slicing in 5G and beyond: Intelligent approaches and challenges
Outline

- 5G Networks
- Network Slicing in 5G
- Slicing Standards
- Artificial Intelligence in 5G networks
- The proposed model
- Conclusion
5G Networks at a glance

5G network:
- Wide range of services and devices
- High speed data transfer
- Existing networks with conventional design

The goal:
- Minimizing the total cost of network infrastructure
- Maximizing system performance and efficiency

Enabling technologies:
- Software defined network (SDN)
- Network function virtualization (NFV)

The goal:
- Having a flexible and highly adaptable network
- Handling a variety of services simultaneously
Main applications for 5G networks fall into three categories:

- **Massive Machine Type Communication (mMTC):** Smart city, etc.
- **Enhanced mobile broadband (eMBB):** Ultra-high definition video, 3D video, etc.
- **Ultra-reliable and low latency Communication (URLLC):** Driverless, industrial automation, etc.
Network Slicing in 5G (Concept and Architecture)

Network Slicing:
An E2E logical subnet including
1. Core Network
2. Radio Access Network
3. Transport Network

Architecture of network Slicing:
1. Service instance layer
2. Network slice instance layer
3. Resource layer
Ericsson and Deutsche Telekom share slice of success in 5G on-demand video service trial
Slicing Standards

There are many standards considering slicing in different parts of the network. Here we have brought a number of these standards:

**Radio Access Network:** 3GPP RAN

- **Release 15:** Present Key principles for supporting network slicing in NG-RAN, enhancement of some implementation dependent features.

**Transport Network:** ITU-T SG15

- The international standards (ITU-T Recommendations) developed by Study Group 15.

**Mobile Core Network:** 3GPP SA

- **Release 15:** Considering basic network slice features
- **Release 16:** enhancements of network slicing enhancements of Service-based Architecture (SBA) higher flexibility and better modularization full-scale virtualization
- **Release 17:** Several parameters of the GST parameters studied in order to keep SLS
Artificial Intelligence: Special Groups for AI

AI has become so widespread that Standardization Bodies have formed some specific ICT groups for standardization of AI.
Some of these specific groups are as follows:

<table>
<thead>
<tr>
<th>FG-ML5G</th>
<th>IEEE SA</th>
<th>ISO/IEC JTC</th>
<th>ETSI ISG ENI</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="https://via.placeholder.com/50" alt="ITU Logo" /></td>
<td><img src="https://via.placeholder.com/50" alt="IEEE Logo" /></td>
<td><img src="https://via.placeholder.com/50" alt="ISO and IEC Logos" /></td>
<td><img src="https://via.placeholder.com/50" alt="ETSI Logo" /></td>
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</table>
Artificial Intelligence (In Network Slicing)

Artificial Intelligence Revenue, World Markets: 2016-2025

(Source: Tractica)

Number of scientific papers

Al and network slicing in recent years
The Proposed Model

Slicing Functionalities

F.1. Design

F.2. Deployment

F.3. Operation and management

F3.1. Performance management

F3.2. Fault management

F3.3. Security

[Diagram showing the proposed model with stages such as Design, Deployment, Slicing Functionalities, Operation and management, and Orchestration, along with processes like Monitoring, Action, Fault management, Security, and Artificial Intelligence]
F.1. Design

- The first step to have an efficient network
- Answering distinct service needs defined in 5G network
- Processing vast amount of data includes User needs and requirements, working environment and service goals

F.2. Deployment

Network resource provisioning and allocation:

- Under Provisioning: violating Service Level Agreement (SLA)
- Over Provisioning: Wasting resources

2 types of approaches:

- Policy-based
- Auction-based
F.3. Operation and Management

F.3.1. Performance management:

- Admission control: whether network can accept or reject the upcoming slice request
- A wide resource sharing
- A limited resource sharing

F.3.2. Fault management:

- Analyzing the System activities, classifying as normal and flawed
- Recognizing usual and unusual user behavior and traffic
- Locating the precise location of error
- Trying to fix the flaws
F.3. Operation and Management

F.3.3. Security:

- Analyzing the traffic, service requests and status of slice
- Spotting security vulnerabilities and detecting attacks in the slice
- Taking the proper action against threats and attacks

An effective action against attacks:

- Quarantining the contaminated slice to restrict the attack and its following damage to other slices
## Artificial Intelligence (AI) Algorithms

<table>
<thead>
<tr>
<th>Supervised Learning (A1)</th>
<th>Unsupervised Learning (A2)</th>
<th>Reinforcement Learning (A3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nearest Neighbor</td>
<td>k-means clustering</td>
<td>Q-Learning</td>
</tr>
<tr>
<td>Naive Bayes</td>
<td>Association Rules</td>
<td>Temporal Difference</td>
</tr>
<tr>
<td>Decision Trees</td>
<td>t-Distributed Stochastic Neighbor Embedding</td>
<td>Deep Adversarial Networks</td>
</tr>
<tr>
<td>Support Vector Machines</td>
<td>Association rule</td>
<td>Monte-Carlo Tree Search</td>
</tr>
<tr>
<td>Neural Networks</td>
<td></td>
<td>Asynchronous Actor-Critic Agents</td>
</tr>
<tr>
<td>Linear Regression</td>
<td></td>
<td></td>
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<tr>
<td>Logistical Regression</td>
<td></td>
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<tr>
<td>Random Forest</td>
<td></td>
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<tr>
<td>Gradient Boosted Trees</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Artificial Intelligence (AI) Algorithms

(A1): Supervised Learning

(A2): Unsupervised Learning

(A3): Reinforcement Learning

Nearest Neighbor: A supervised learning method that predicts the value of a target variable by finding training examples nearest to it in the feature space.

Naive Bayes: A simple probabilistic classifier that makes predictions based on the probabilities of different classes.

Decision Trees: A decision-making algorithm that constructs a tree-like model of decisions from an observed pattern.

Support Vector Machines: A method for classification and regression analysis that aims to find the hyperplane that maximizes the margin between different classes.

Neural Networks: A complex neural network with multiple layers, which are capable of learning andgeneralizing from the data.

Linear Regression: A regression model that predicts the relationship between one or multiple independent variables and a dependent variable.

Logistical Regression: A regression model that applies a logistic function to a set of independent variables to model a binary dependent variable.

Random Forest: A ensemble learning method that operates by constructing a multitude of decision trees at training time.

Gradient Boosted Trees: An ensemble machine learning method that builds multiple regression models, typically decision trees, in a forward stagewise fashion.

k-means Clustering: A method of vector quantization, originally from signal processing, that is popular for cluster analysis in data mining.

Association Rules: A method for discovering interesting relations between variables in large databases.

t-Distributed Stochastic Neighbor Embedding: A dimensionality reduction technique that is used to embed high-dimensional data into lower dimensions.

Q-Learning: An algorithm used for solving Markov decision processes which can be used for both reinforcement learning and artificial intelligence.

Temporal Difference: A reinforcement learning algorithm that learns the value of an action by comparing the immediate reward to the expected future reward.

Deep Adversarial Networks: A type of neural network that consists of two parts: a generator and a discriminator, which are trained together to maximize the log-likelihood of the data.

Monte-Carlo Tree Search: A method for making decisions in complex or uncertain environments.


Agents: Software programs that make decisions or perform actions in an environment.
## AI Algorithms (Applied in different functionalities)

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<thead>
<tr>
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</thead>
<tbody>
<tr>
<td><strong>F1. Design</strong></td>
<td>60%</td>
<td>20%</td>
<td>20%</td>
</tr>
<tr>
<td><strong>F2. Deployment</strong></td>
<td>21.7%</td>
<td>4.1%</td>
<td>74.1%</td>
</tr>
<tr>
<td><strong>F3. Operation &amp; Management</strong></td>
<td>41%</td>
<td>16%</td>
<td>41%</td>
</tr>
</tbody>
</table>
Conclusion

We found about half of the papers in this subject have studied AI algorithms in the **F.2. Deployment**. This might be due to high AI applicability in **resource provisioning and allocation** which are the main functions of deployment.

The further comparison between other functionalities is depicted in the figure below.

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**Slicing Functionalities**

<table>
<thead>
<tr>
<th>Functionality</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>F.1. Design</td>
<td>6.9%</td>
</tr>
<tr>
<td>F.2. Deployment</td>
<td>42.3%</td>
</tr>
<tr>
<td>F3. Operation and management</td>
<td></td>
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<tr>
<td>F3.1. Performance</td>
<td>19.5%</td>
</tr>
<tr>
<td>F3.2. Fault</td>
<td>17.5%</td>
</tr>
<tr>
<td>F3.3. Security</td>
<td>13.8%</td>
</tr>
</tbody>
</table>

Percentage of researchers focus on applying AI in different functionalities
Conclusion

In the paper we did the following items which some of the important ones have been described in this presentation.

- Reviewing 5G network, network slicing concepts, service categories and architecture
- Highlighting the specific working groups for AI in the ICTs standardization bodies
- Investigating Critical role of AI techniques in network slicing automation
- Proposing a functionalities model for AI-based network slicing
- Exploring the researchers focus on applied AI in network slicing functionalities
Thank you!