ITU KALEIDOSCOPE
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Machine learning for a 5G future

Consideration on Automation of 5G Network Slicing with Machine Learning

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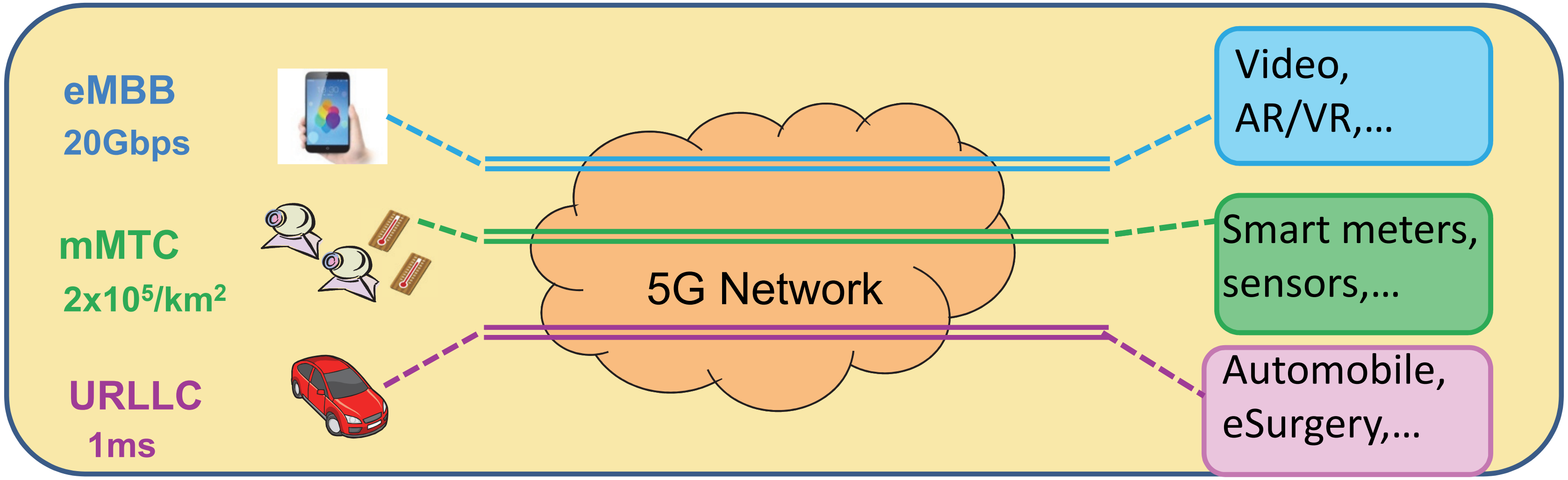
Presentation outline

- Introduction
- Network slicing overview
- Network automation functions
- Machine learning (ML) techniques for networking
- AI/ML for networks in SDOs and forums
- Conclusion

Introduction

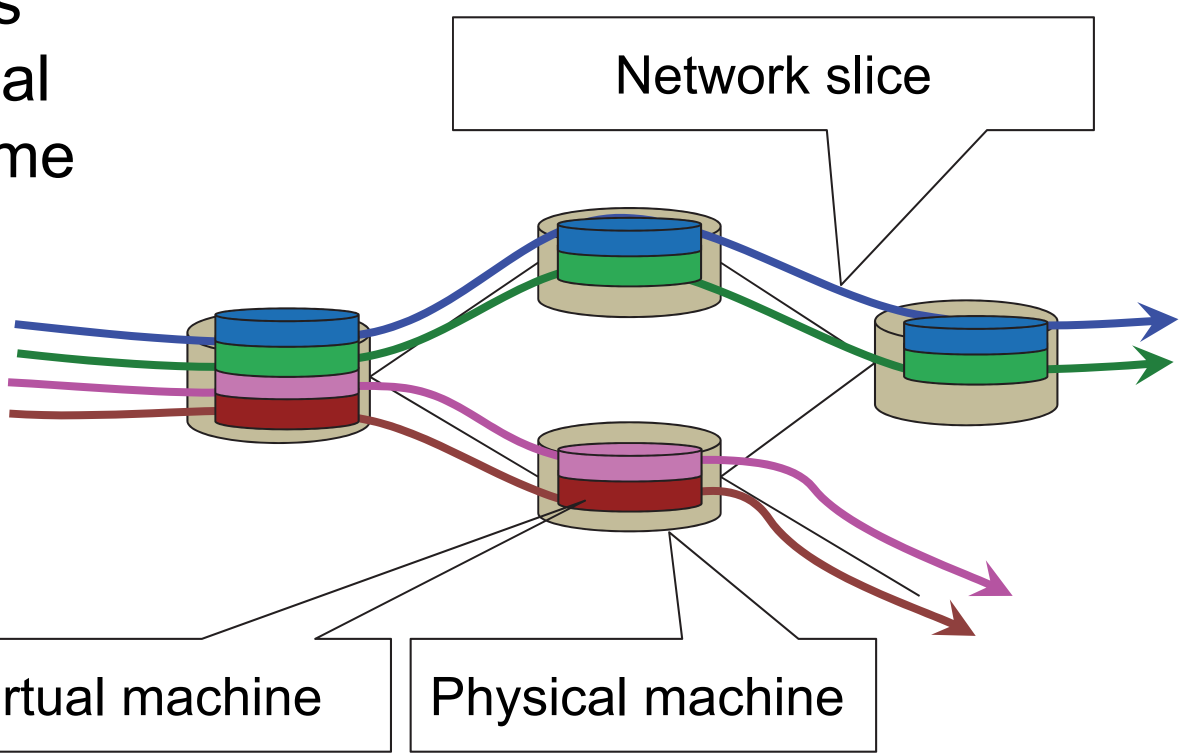
- Various services in 5G/IMT-2020 networks, diverse requirements:
  - eMBB: very high throughput
  - mMTC: large connection density
  - URLLC: ultra-low latency



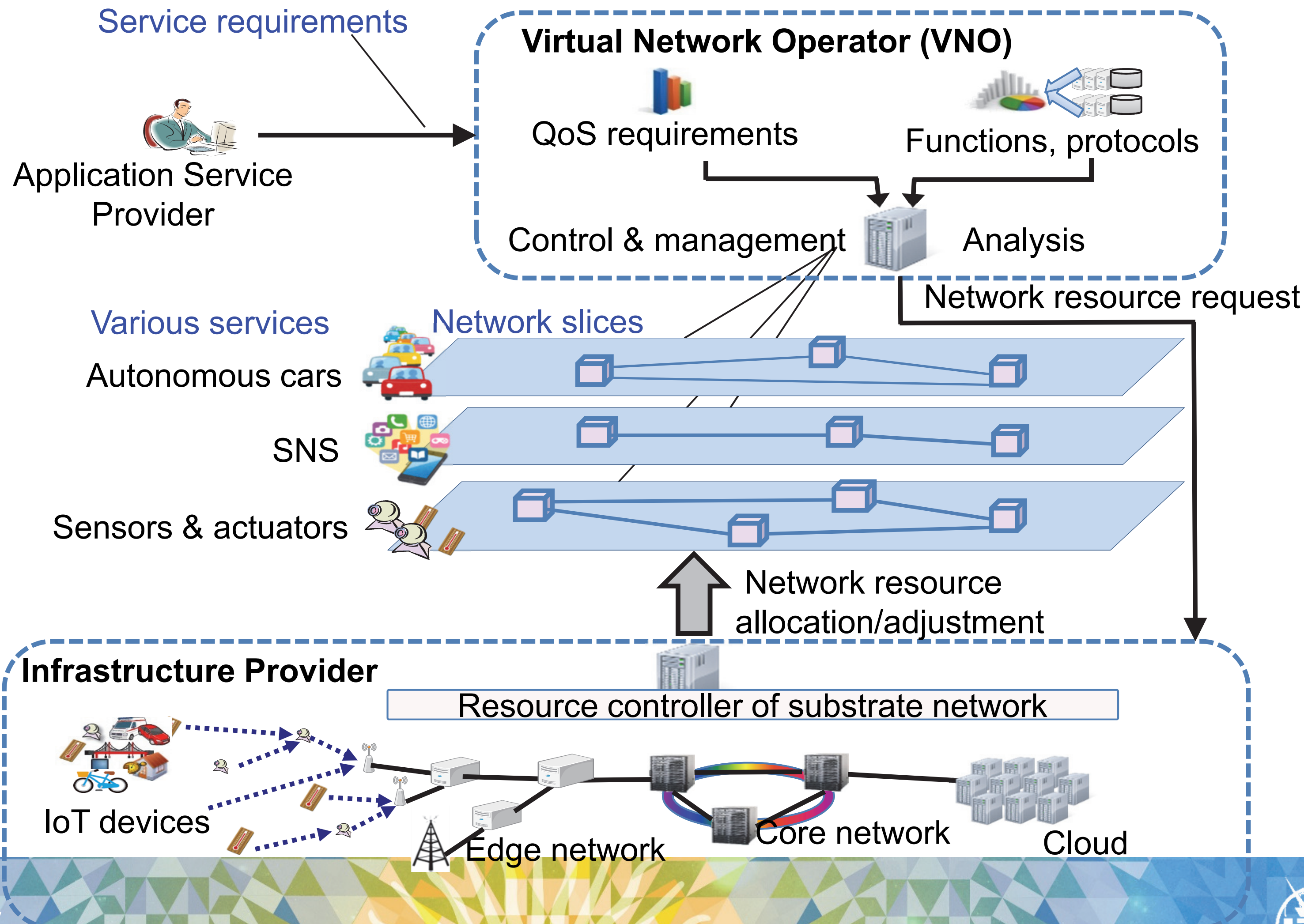
- Different services be served through network slices

Network slicing concept

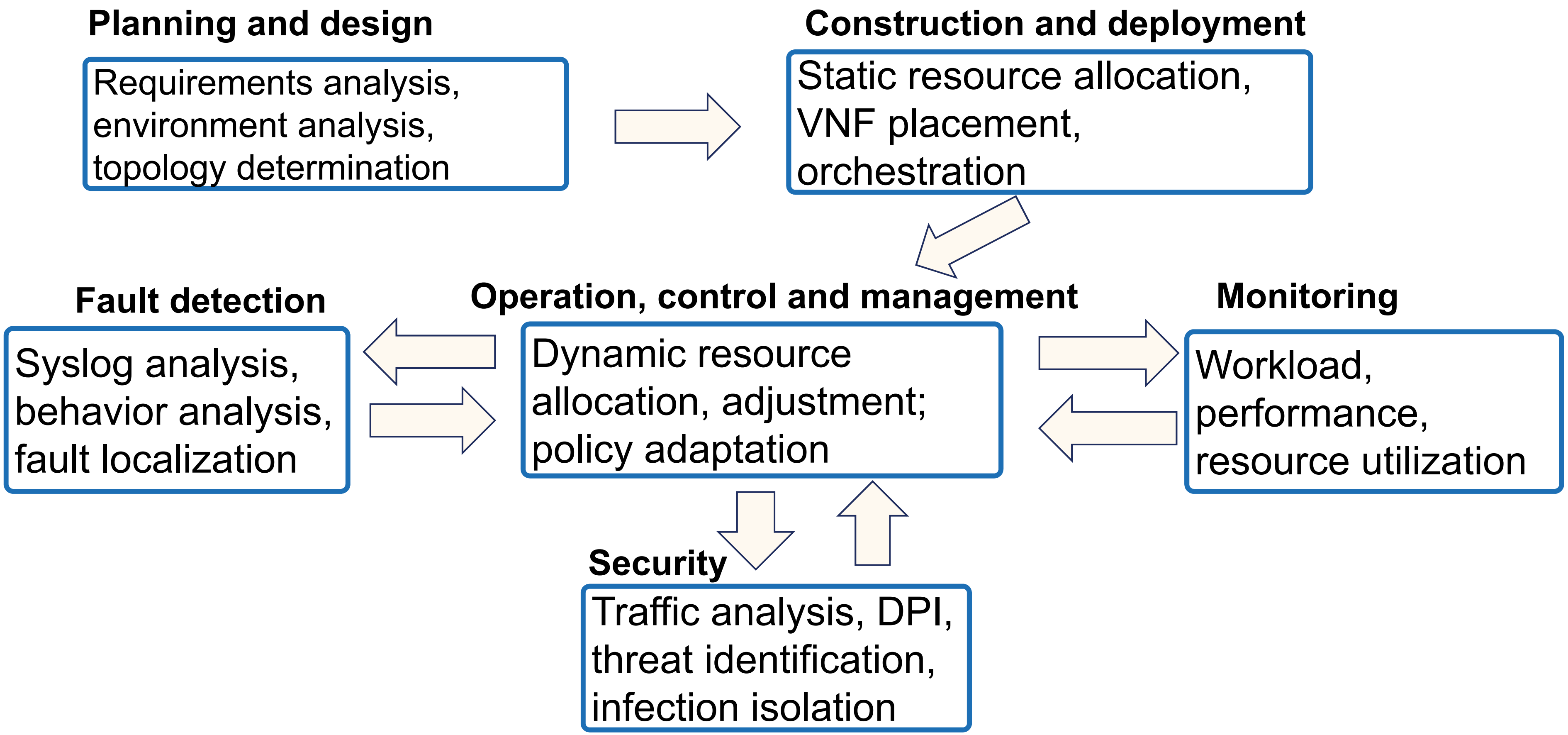
- Network slicing allows creating multiple virtual networks over the same physical network
  - SDN and NFV are supporting techniques



Network slices creation process flow



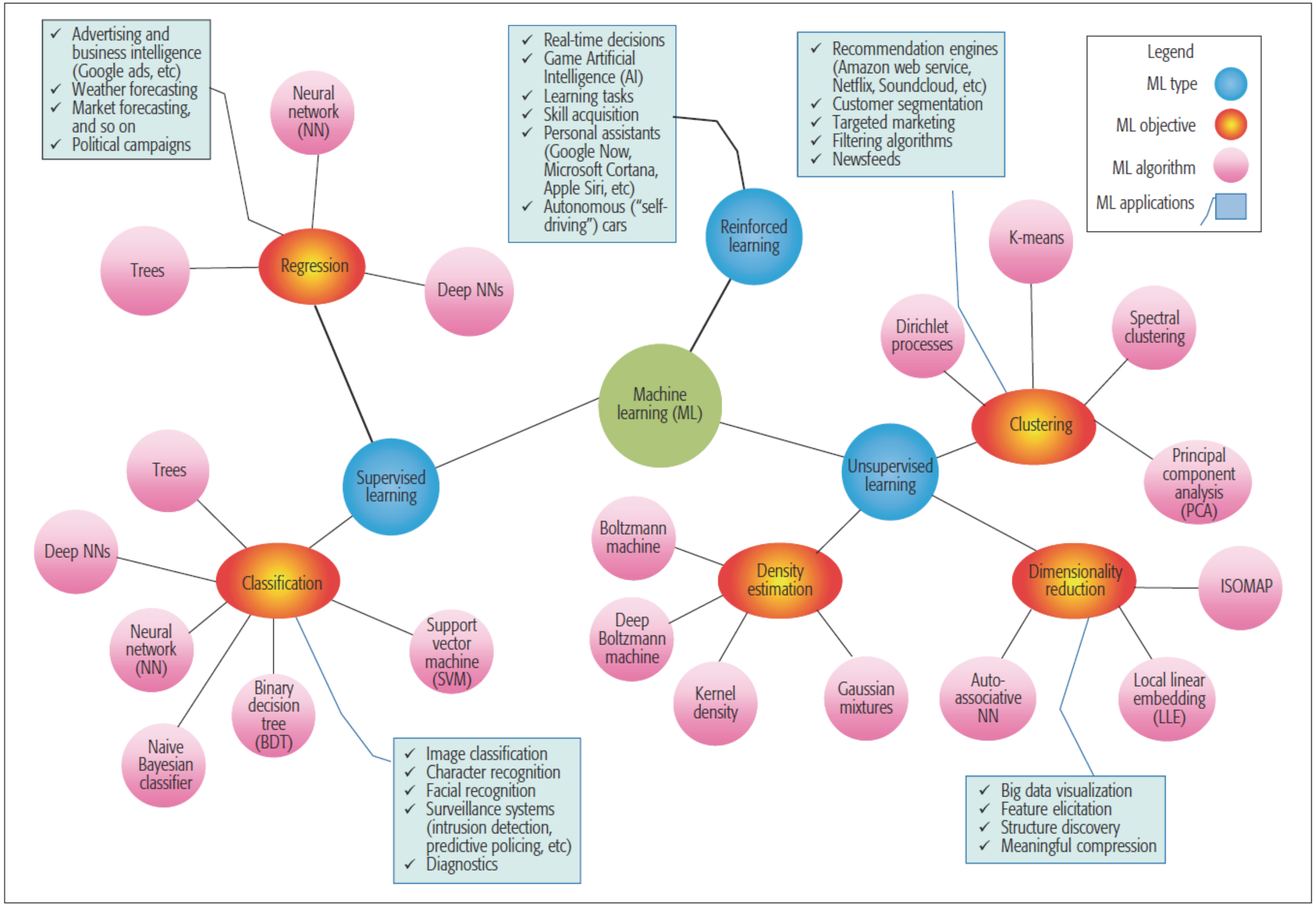
Network functions requiring automation



Machine learning for networks – overview (1/3)

- Classification of machine learning techniques-

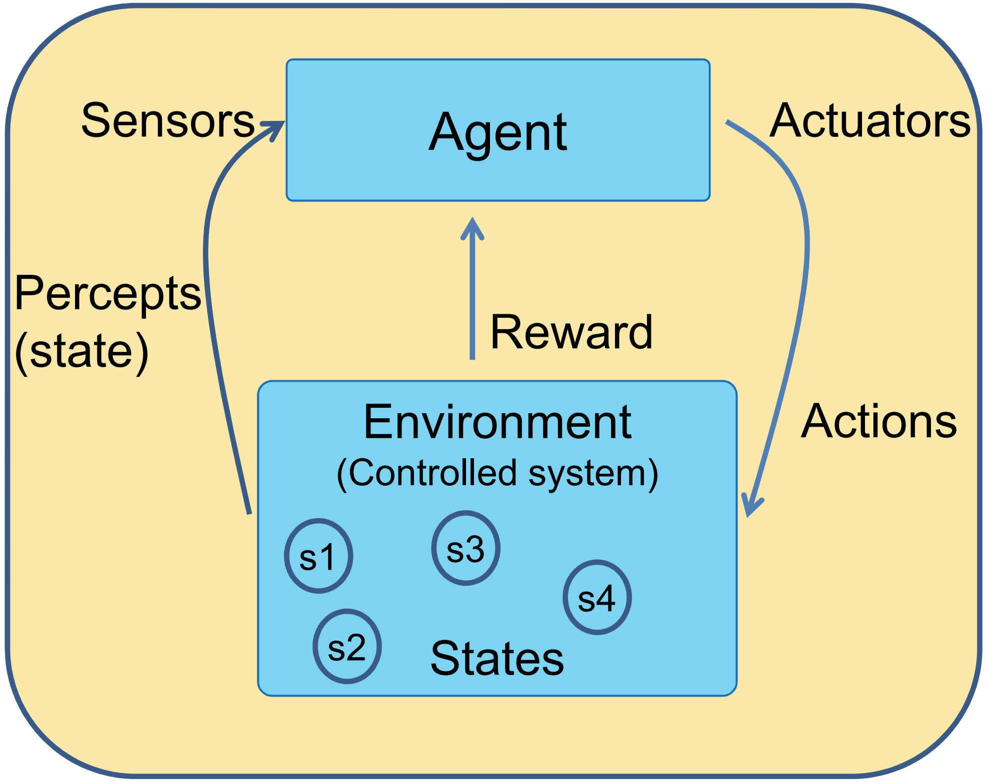
Figure source: N. Kato, et al., IEEE Wireless Commun., June 2017.



Machine learning for networks – overview (2/3)

- Reinforcement learning (RL) -

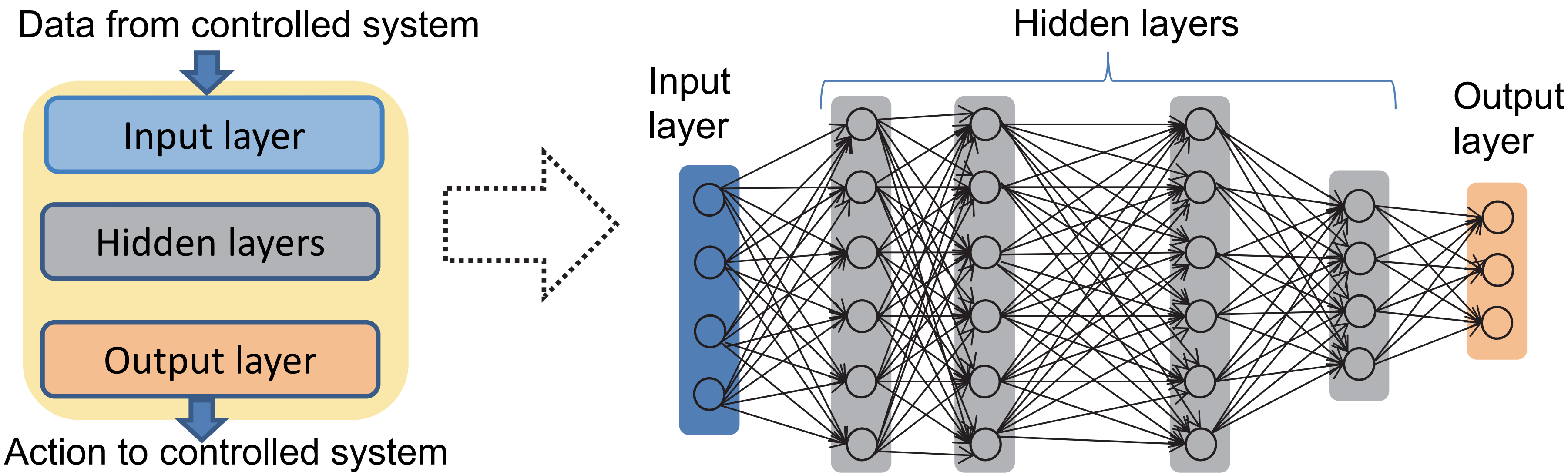
- RL achieves goals through experience
- RL agent gets percepts, performs actions to maximize rewards
- Two factors characterizing RL techniques:
    1. State transition model, e.g. known (e.g. MDP), unknown
    2. Action policy, e.g. maximizing cumulative reward attainable from all future steps.



Machine learning for networks – overview (3/3)

- Deep learning -

- Based on artificial neural network
- Learn and recognize patterns by processing a huge volume of data, without requiring highly tuned or many rules
- Learning can be supervised, semi-supervised, or unsupervised



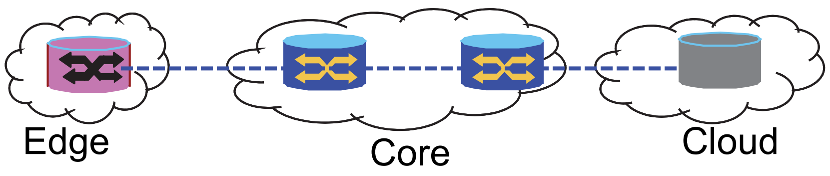
Network function and relevant ML techniques

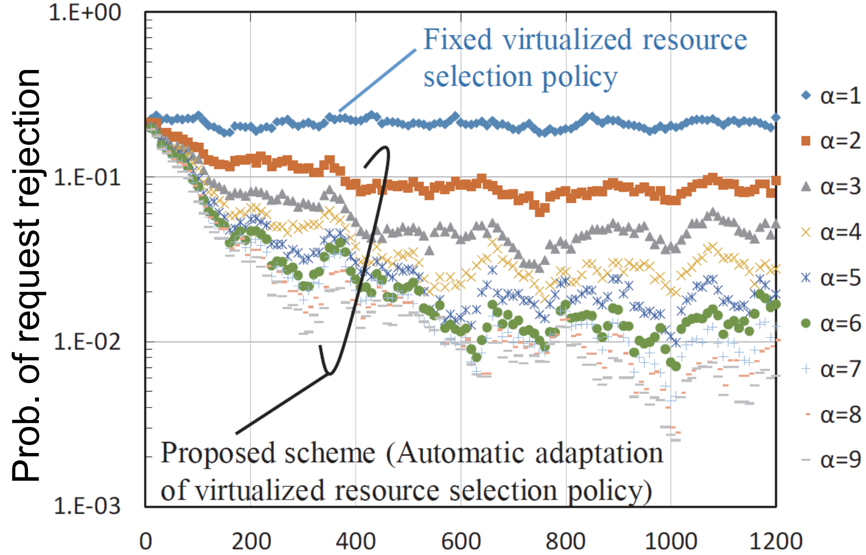
- Part 1-

Network functions	Machine learning techniques	Purposes
Planning and design	Support vector machine Gradient boosting decision tree Spectral clustering Reinforcement learning	- Classification of service requirements - Forecasting trend, user behavior - Configuration of parameters
Operation and management	K-mean clustering Deep neural network Reinforcement learning	- Clustering cells, users, devices - Routing, forwarding, traffic control - Decision making for dynamic resource control, policy formulation - Reconfiguration of parameters

Example of ML for network operation: Network resource classification policy adaptation by SVM

Total end-to-end resources = 1000 units





Time elapsed from the occurrence of an urgent contingency to the arrival of mission-critical VN service request

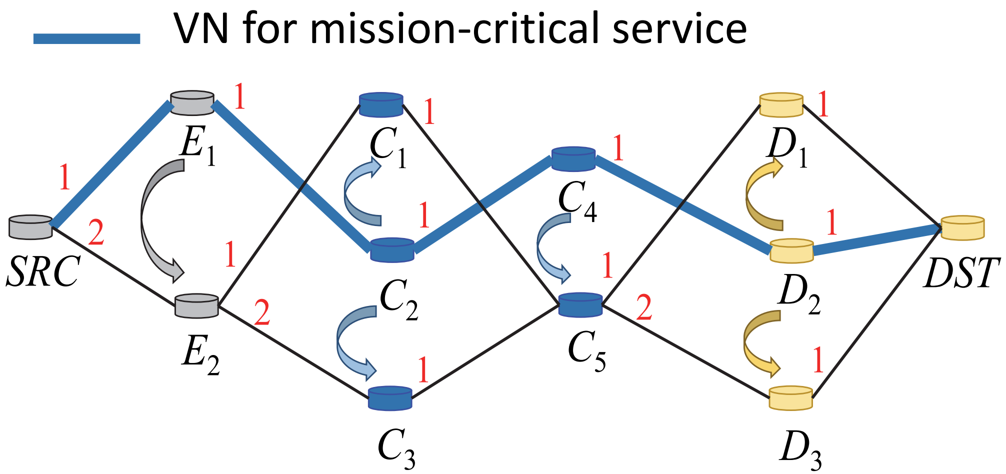
Scenario:

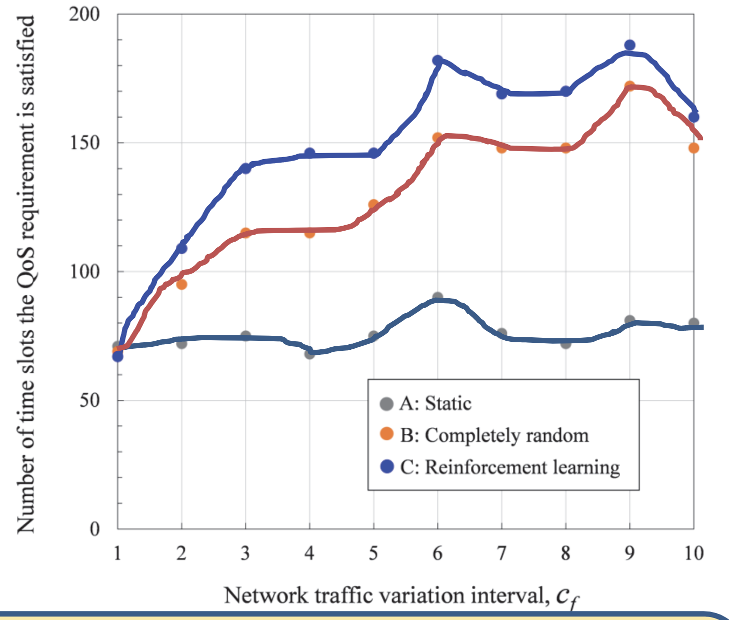
- End-to-end network has 1000 units of resources: classified into type 1 (100 units) and type 2 (1 unit)
- Appling SVM to determine classification boundary
- Two types of VN service requests: mission-critical, and best-effort (BE) arriving as Poisson process
- Measuring probability of mission critical service request rejection due to insufficient resources

Results: Low probability of rejection with resource type classification by SVM

- α represents number of BE services allocated with type 2 for every type 1 allocation

Example of ML for network operation: Network resource adaptation with reinforcement learning





Scenario:

- When mission-critical service request arrives, move VNs of best-effort services to other routes
  - In such as way that QoS requirements are met despite fluctuation of traffic
- Three approaches (static, random, reinforcement learning) are applied in 300 time slots.

Results: Better resource adaptation decision with reinforcement learning

- QoS requirements are met in most time even in faster changes in network traffic

Network function and relevant ML techniques

- Part 2-

Network functions	Machine learning techniques	Purposes
Monitoring	Spectral clustering K-mean clustering Support vector machine Deep neural network	- Clustering of syslog data - Classification of operation modes - Forecasting resource utilization trend
Fault detection	Principal component analysis Independent component analysis Logistic regression Bayesian networks	- Classification of operation data - Detection of network anomaly - Predicting unusual behavior
Security	Deep neural network Principal component analysis	- Clustering users and devices - Detecting malicious behavior - Intrusion detection

AI/ML for networks in SDOs and forums

- ITU-T FG ML5G (Est. in 11/2017)
  - Studying network architectures, use cases, and data formats for the adoption of machine learning methods in 5G and future networks.
- ETSI ISG ENI (Experiential Network Intelligence) (Est. in 2/2017)
  - Defining a cognitive network management architecture based on AI methods and context-aware policies; five deliverables have already been released
- ISO/IEC JTC 1/SC 42 Artificial Intelligence (Est. in 10/2017)
  - Developing ISO standards on big data reference architecture, AI concepts and terminology, and AI systems framework, etc.
- TM Forum Smart BPM (Business Process Management)
  - Investigating the applicability of AI-based decision modeling in telecom business processes for resource provisioning, fault management, QoS assurance, and customer management

Conclusion

- Summary
  - Presented 5G network slicing scenarios and related functions requiring automation
  - Discussed machine learning techniques for network function automation and showed performance improvement in two cases:
    - Support Vector Machine for resource classification
    - Reinforcement Learning for resource adaptation
- Standardization relevancy
  - This work is related with ITU-T Study Group 13
  - Its use cases also discussed in FG ML5G (this week in Tokyo)

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Thank you