An Initial Survey of Artificial Intelligence Approaches to Network Management

***Abstract*—From my point of view, the artificial intelligence (AI) based network management (NM) could be five classifications: fault, configuration, accounting, performance and security management. In my mind, the next step: write a survey as the start of my research and have a test to understand AI and NM in depth. After the meeting, we have a better next step that narrowed the network management into flexible industrial automation application integrated with AI and continue to research the state of the art. Meanwhile, we make a simple outline of the topic and find its possibility to apply the European research project together with HDU and other relevant organizations.**[1]

***Index Terms*—Review, Artificial intelligence, Network Management**

I. Introduction

For past three weeks, my biggest gain is that I have an overview of AI-based NM although I do not understand all of the papers well after a sample survey of over 50 papers. During this time, the deepest impressions are that at the very early year, even earlier than 1990's, there has been various papers discussing every aspect of network management using AI technologies. To date, definitely, it has become much hotter. The differences are nowadays we use much more complex algorithms and we have much more strong computing ability and much more kinds of application scenarios.

For AI, when we talk it, in most cases, we mean machine learning. Normally, machine learning is divided into three learning paradigms: supervised, un-supervised and reinforcement learning. When we want to implement some applications. We should also usage some theory or technologies for related paradigm, such as Bayesian theory, Support Vector Machine (SVM), Hidden Markov Model, Q-learning or various kinds of Neural Networks etc.

Meanwhile, there are various types of communication network appeared in papers: wireless network, cellular network, optical network, IP network, ad hoc network, radio network etc.

Hence, when AI meet NM. We get more concepts, such as machine learning based, AI-based, self-organize (self-configuring, self-healing, self-optimizing and self-protecting), cognitive together with types of network.

Furthermore, lots of labs are focusing on these concepts. Table I shows the information of part of the labs. To my best knowledge, it is ranked by importance and of course, it is not complete. I will continuously update this survey.

As the most important thing, the classification of NM direction is defined differently by different researchers.

Kumar, et al. [1], in 1997 a very early year, give an overview of the AI in NM which is classified into **fault management, configuration management, accounting management, performance management, security management** but more expert system than AI technologies are discussed. 20 years later, [2] from University of Waterloo describes the overview of machine learning as the same classifications meanwhile they have explained more machine learning technologies and provided an impressive framework named C-MAPE (Cognitive-Monitor-Analyze-Plan-Execute over a shared Knowledge) in FIG.1. This kind of classifications comes from **Telecommunications Management Network (TMN) Recommendations** [3].

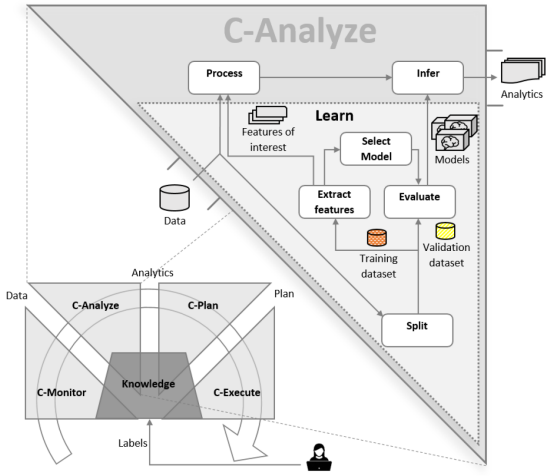

Fig. 1. C-MAPE.

Then, in [4], Boutaba, et al. have a much more comprehensive discussion of machine learning on networking which has over 500 citations. It contains 8 directions: **traffic prediction, traffic classification, traffic routing, congestion control, resource management, fault management, QoS and QoE management, network security** and each direction has its subsections, illustrated in FIG. 3.

Li Rongpeng, et al. [5] presents the AI int context of 5G and have a different view of the classifications which are **radio resource management, mobility management, management and orchestration, service provisioning management**.

Jiang and Hanzo Lajos in [6] also provides a machine learning paradigms in 5G shown in FIG. 2. They distinguish the applications as the type of machine learning.

Then, under the guide of these survey, I read some papers simply and when I have a look of a paper, I will record something to its related section below.

[1] the blue sentences are the ideas after the meeting.

TABLE I
INFORMATION OF LABS WORKING ON AI-BASED NM

Head	Country	University	Personal Articles	collected papers	key words
R. Boutaba	Canada	University of Waterloo	199	2	
Honggang Zhang	China	Zhejiang University	190	7	
Hanzo Lajos	UK	University of Southampton	1216	2	
Petri Mähönen	Germany	RWTH Aachen University	235	1	
P. Venkataram P	India	Indian Institute of Science	143	2	
Xiangming Wen	China	Beijing University of Posts and Telecommunications	210	2	
Qadir J.	Pakistan	National University of Sciences and Technology	67	1	

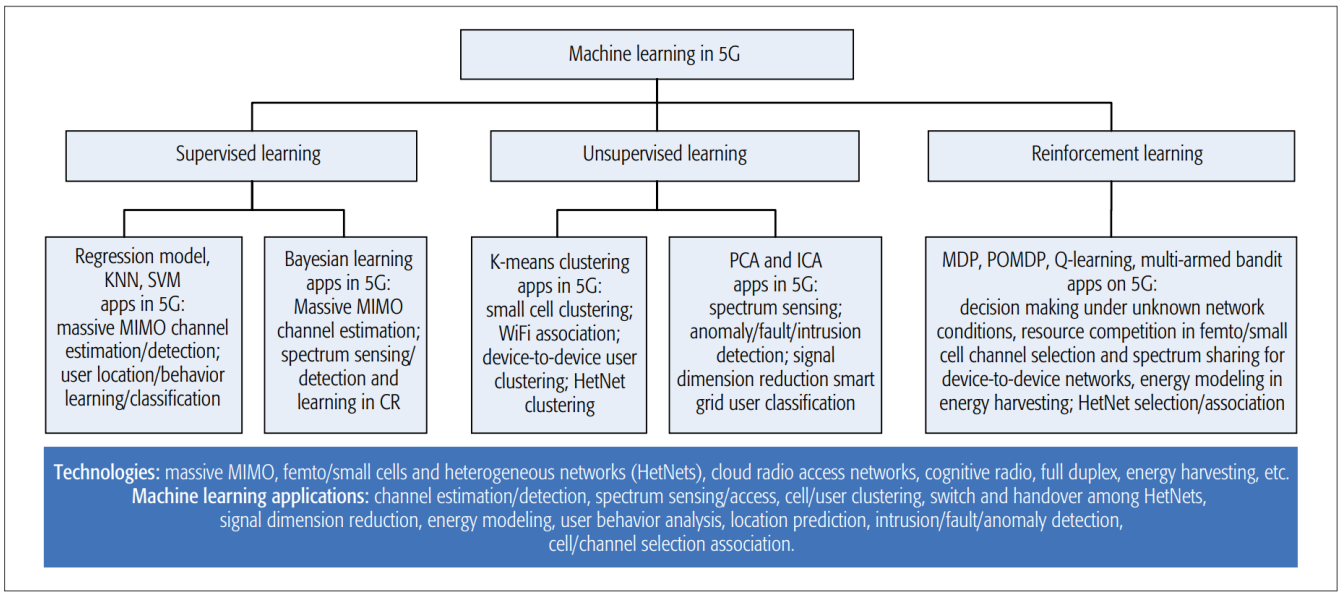

Fig. 2. Machine Learning in 5G.

II. OVERVIEW OF AI

A. Supervised Learning

B. Un-supervised Learning

C. Reinforcement Learning

III. OVERVIEW OF NM

A. Traffic Classification

[7] is a review of traffic classification. Then a lot of papers [8]–[10] discuss about it.

B. Traffic Prediction

[11] from Zhejiang University is about traffic prediction.

C. Traffic Routing

Qadir [12] from Pakistan gaves us a review about congnitive routing.

[13], [14]

D. Mobility Management

[15] poses a AI framework for wireless NM which is used in a case of mobility management, where a ping-pong problem is addressed.

E. Resource management

[16], [17] are about spectrum management.

F. Fault Management

The key elements in fault management are: fault prevention, fault detection, fault localization and isolation, fault repair and restoration.

[18] is a very early paper using machine learning without specify of it.

[19] uses the log data to train the Bayesian network for fault detection and provides a wired office network

[20] presents a dynamic Bayesian Network for large IP network which improves the problem of [19] that dynamically evolve over time.

[21] poses a limited method of NN to estimate the dependability of a 2G wireless network.

[22], [23]

[24] is a framework of machine learning.

[25] poses a ML method based on physical indicates in optical networks.

[26]

Fault detection [27] is a early paper discussing fault detection using NN.

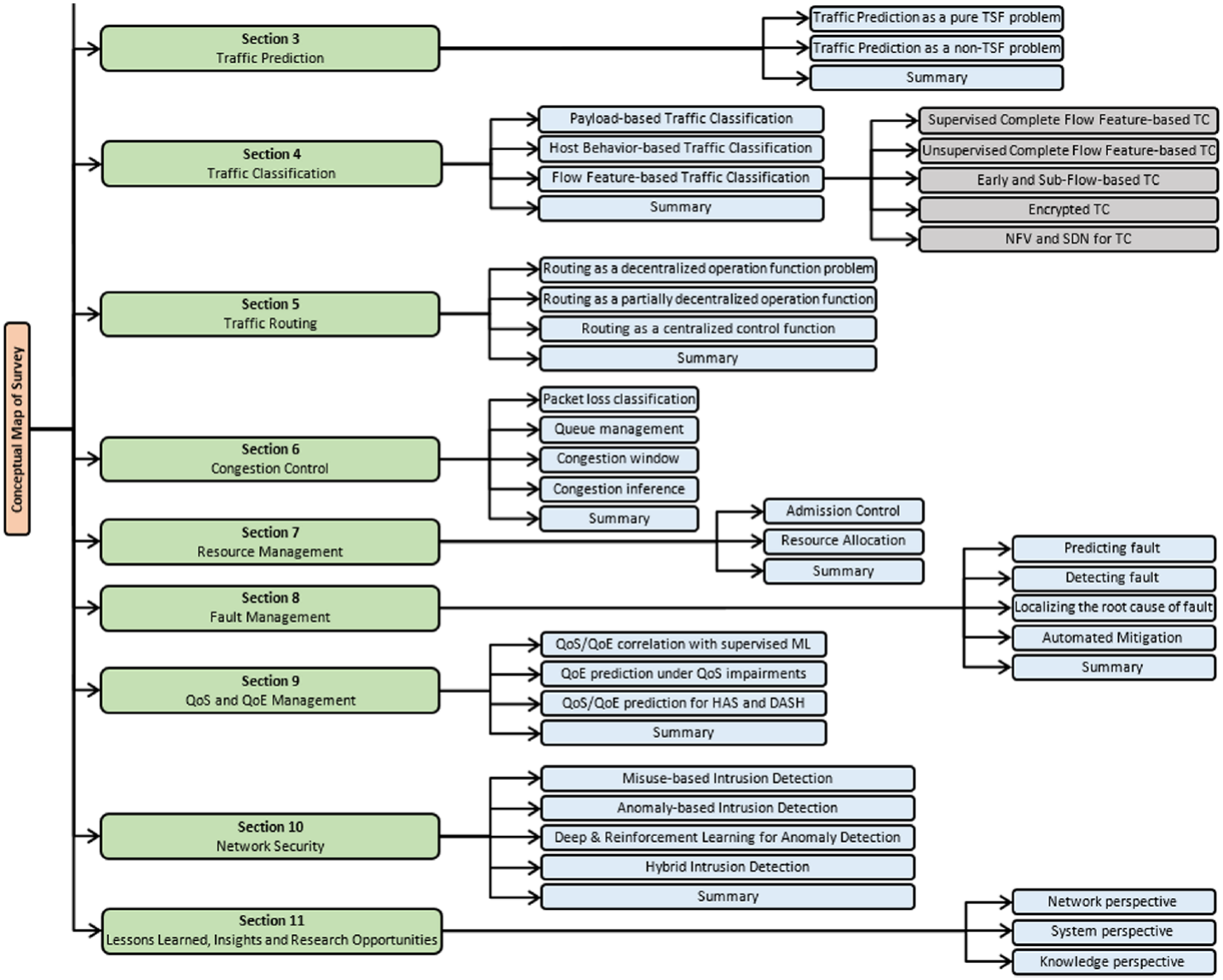

Fig. 3. Machine Learning in Networking

[28] propses a method of Operational Fault Detection whose fault or alarm thresholds are determined by learning expected deviations during a training phase.

[29] build a real-time fault detection and classification model.

[30] select 12 features and use the traffic patterns to form clusters that represent normal traffic, link failure, server crash, broadcast storm and protocol error.

[31] detect faulty nodes in a WSN using RNN.

[32] propose an unsupervised fault detection mechanism.

[33] use different unsupervised algorithms to detect faults in a broadband service provider network that serves about 1.3 million customers.

[34]

G. Performance management

[35] used the RL to turning the management when performance degradation occurs. From my point of view, it have used the DQL (Deep Q-learning).

H. Security Management

[36], [37]

I. Service Management

[38] uses a reinforcement learning approach to optimize service.

[39], [40] presents reinforcement approachs to service slicing.

J. Platform

[41] pose a platform of AI-based NM.

IV. A Case of Reinforcement Learning

V. Conclusion

After having a look of these papers, I strongly agree with the 5-type classification: **fault, configuration, accounting, performance and security management**. I think fault, performance and accounting management are three stages of NM. Configuration and security management effect throughout the NM.

Since the past papers are too much of all 5 classifications, I think I must narrow my topic into one of them firstly.

If I should select one from the 5, the fault management would be better. Because it is the first step of NM. However, several questions are still confused me. Firstly, to my best knowledge, as far as I know, lots of work also have been done on fault management. Maybe if we further narrow it to industry or automation then the situation maybe changed. On the other hand, I want my topic which would be usable to some further projects and could be studied for a long time, not just limited to PhD study and could be based on ifak's past research. From my point of view, these three points are important but I do not know how to deal with it. Additionally, if fault management is the topic, is it relatively a little bit easier to do some experiment or have some implementations later. After the meeting, most of the confusions are clarified.

If the topic has an initial decision. For the next stage, I plan to do two things.

1) Write a survey of my topic as the beginning of my research and hopefully it will be published in a journal.
2) Have a test of wireless AI which will let me know both NM and AI in depth.

After the meeting, since the network management could be narrowed into flexible industrial automation application, we have the new next step:

1) Continue to research the state of the art and make a simple outline of the topic.
2) Find the possibility to apply the European research project together with HDU and the application deadline of the possible European project is 2019.3.

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