Network Management and AI

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IEEE Summit on Communications Futures 2020.
Honolulu, Hawaii, January 18, 2020

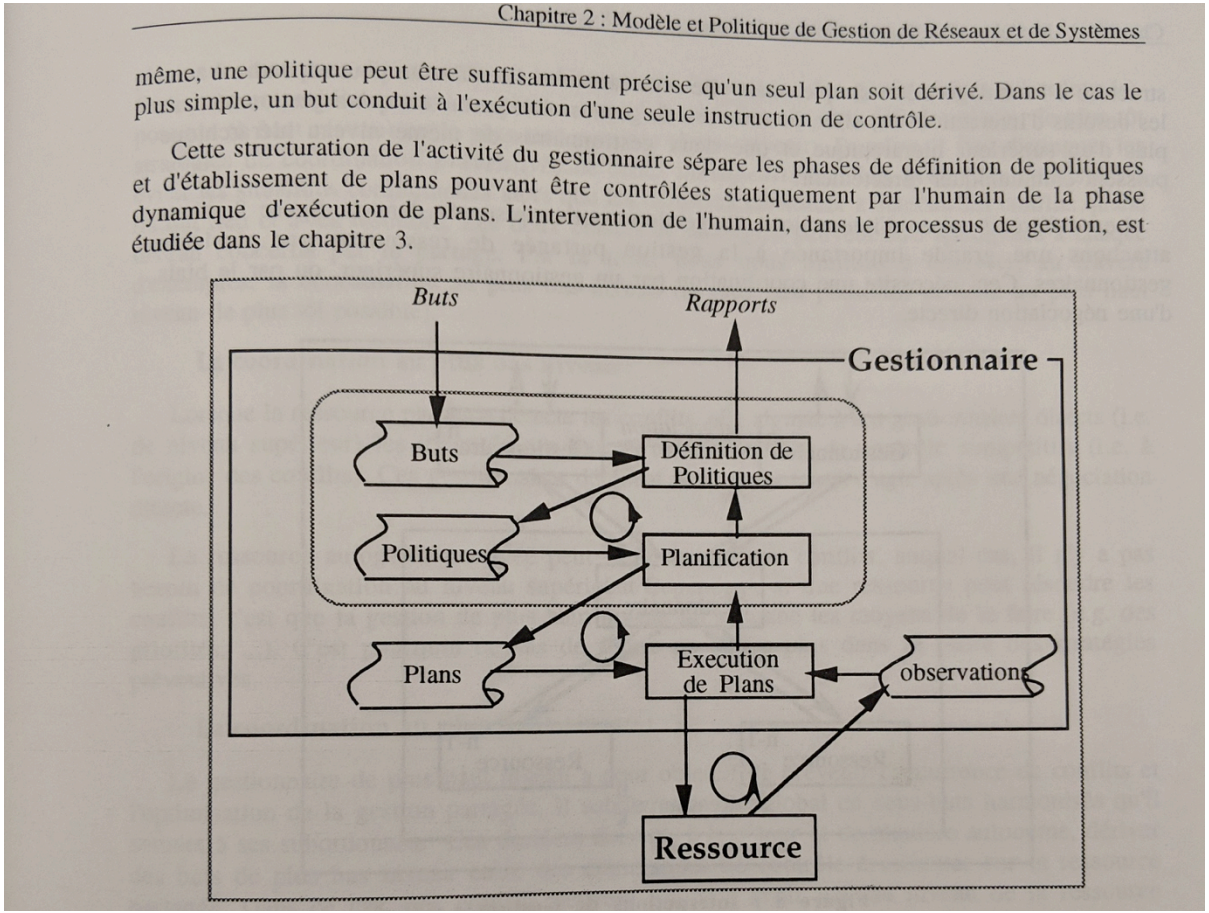
Outline

- Network Automation
- A Walk Down the Memory Lane
- Recent Incarnations
- Can it Happen this Time ?
- Take-away

Network Automation

- What?
  - Networks capable to autonomously monitor their status, analyze problems, make decisions, and execute corrective actions with minimal to no human intervention.
- Why?
  - Traditionally network management has been human-centric
    - Costly, error-prone, and slow to adapt to changes
    - Cannot cope with the increasing complexity due to
      - Large number and diversity of network devices
      - Future application requirements, e.g., high-capacity, ultra-low latency, very high reliability, and massive connectivity.

A Walk Down the Memory Lane



Chapitre 2 : Modèle et Politique de Gestion de Réseaux et de Systèmes

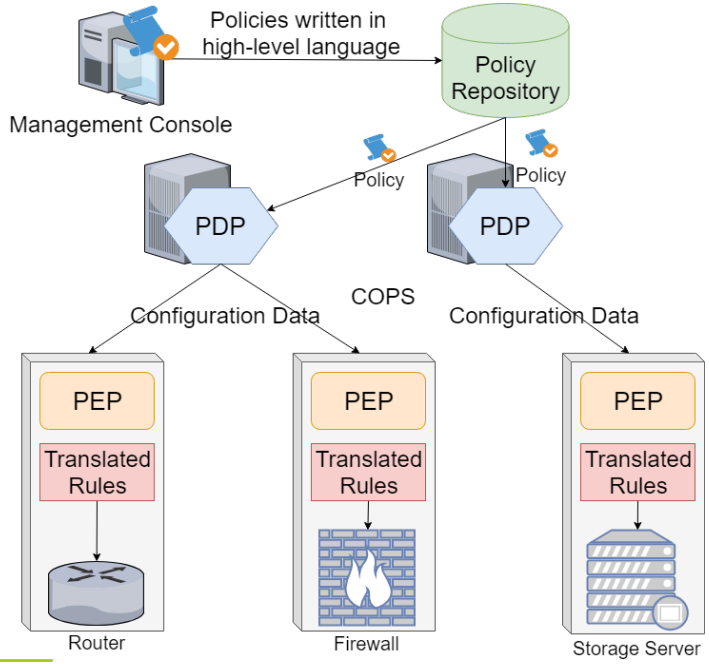
même, une politique peut être suffisamment précise qu'un seul plan soit dérivé. Dans le cas le plus simple, un but conduit à l'exécution d'une seule instruction de contrôle.

Cette structuration de l'activité du gestionnaire sépare les phases de définition de politiques et d'établissement de plans pouvant être contrôlées statiquement par l'humain de la phase dynamique d'exécution de plans. L'intervention de l'humain, dans le processus de gestion, est étudiée dans le chapitre 3.

R. Boutaba. PhD thesis. 1994
Université Pierre et Marie Curie
(Now Sorbonne Université).

A Walk Down the Memory Lane

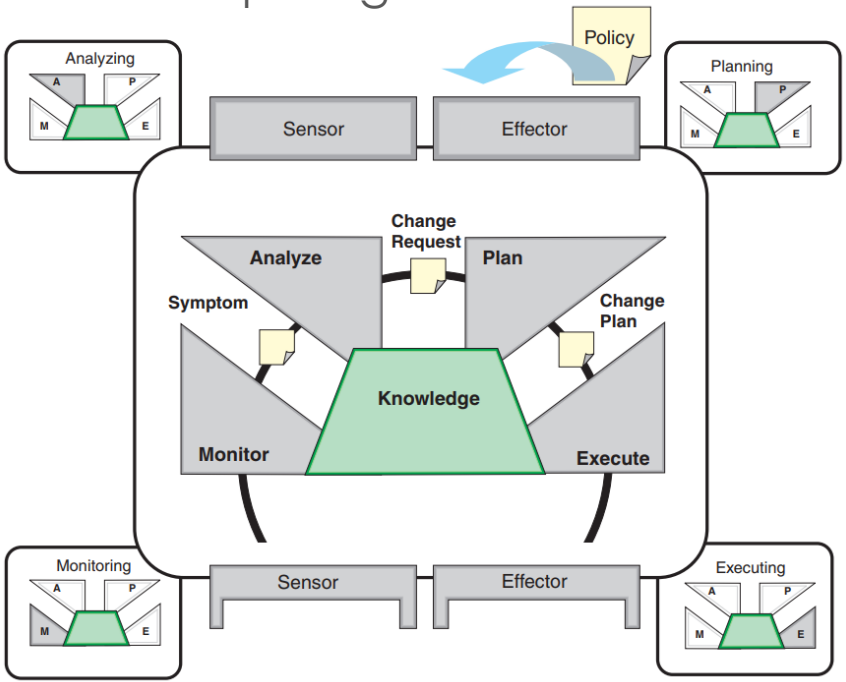
- Policy-based Management (PBM)



The COPS (common open policy service) protocol. IETF RFC 2748, 2000.

A Walk Down the Memory Lane

- IBM Autonomic Computing



Jeffrey O. Kephart, David M. Chess. The vision of autonomic computing, IEEE Computer, 36(1): 41-50. 2003

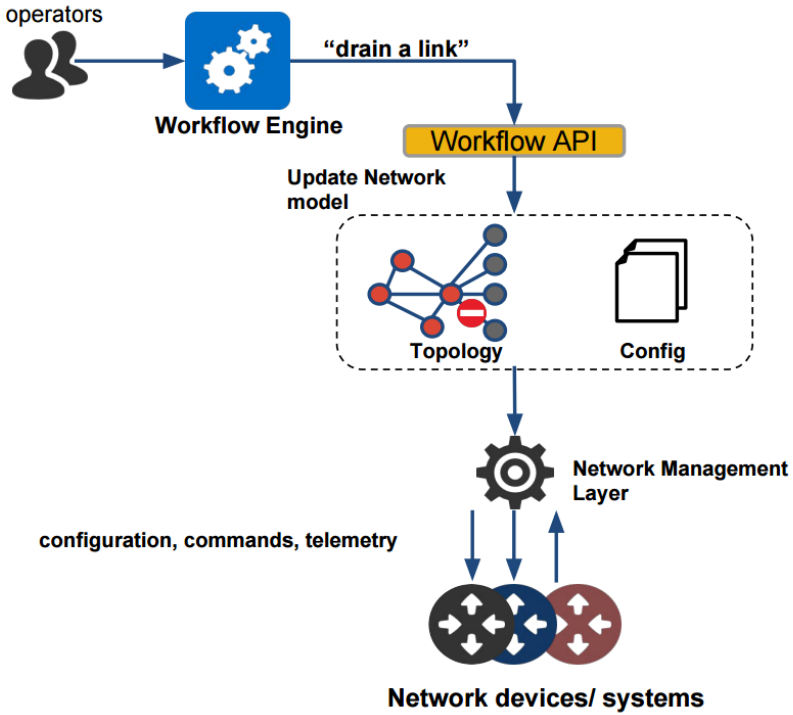
Why Practical Deployments Remained Unrealized?

- Reliance on proprietary hardware with little to no programmability
- Lack of global visibility restricting network-wide optimizations
- Inability to extract knowledge from network monitoring data at scale

Re(cent)incarnations

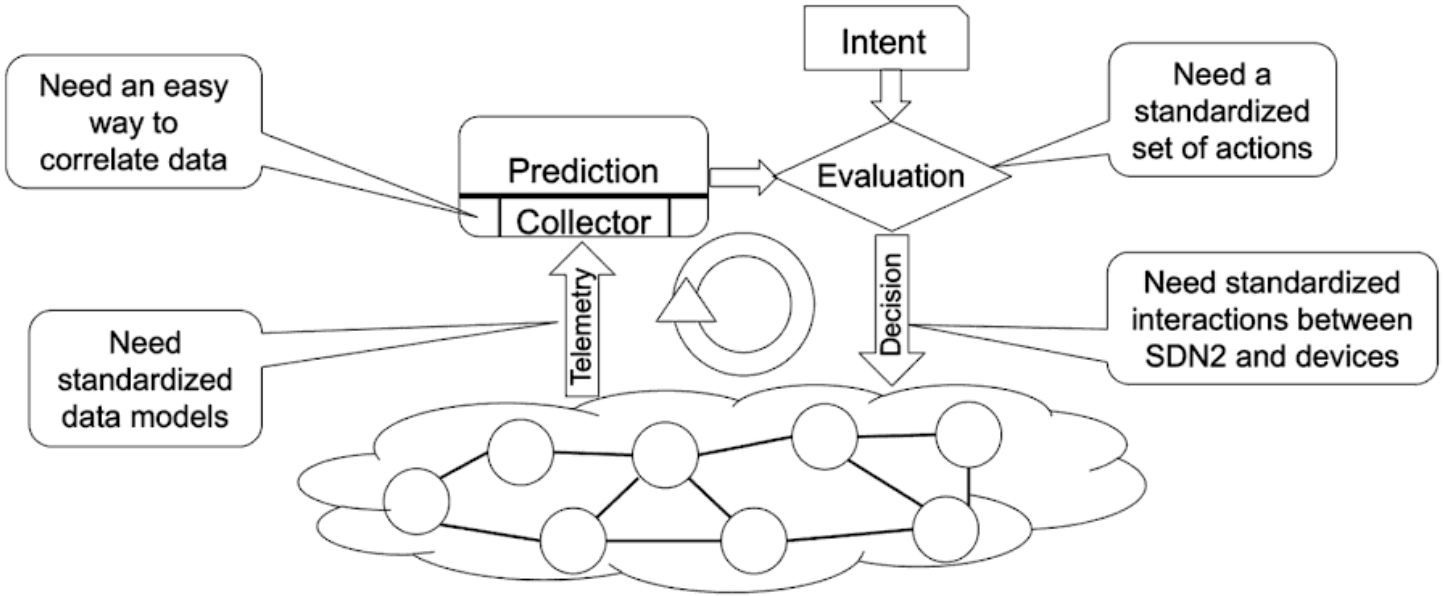
- Google Zero Touch Network
- Juniper Self-Driving Networks
- Open Network Automation Platform (ONAP)
- ETSI Zero-touch Network and Service Management (ZSM) Industry Standards Group
- Knowledge-defined Networking
- …and more

Google's Zero Touch Network



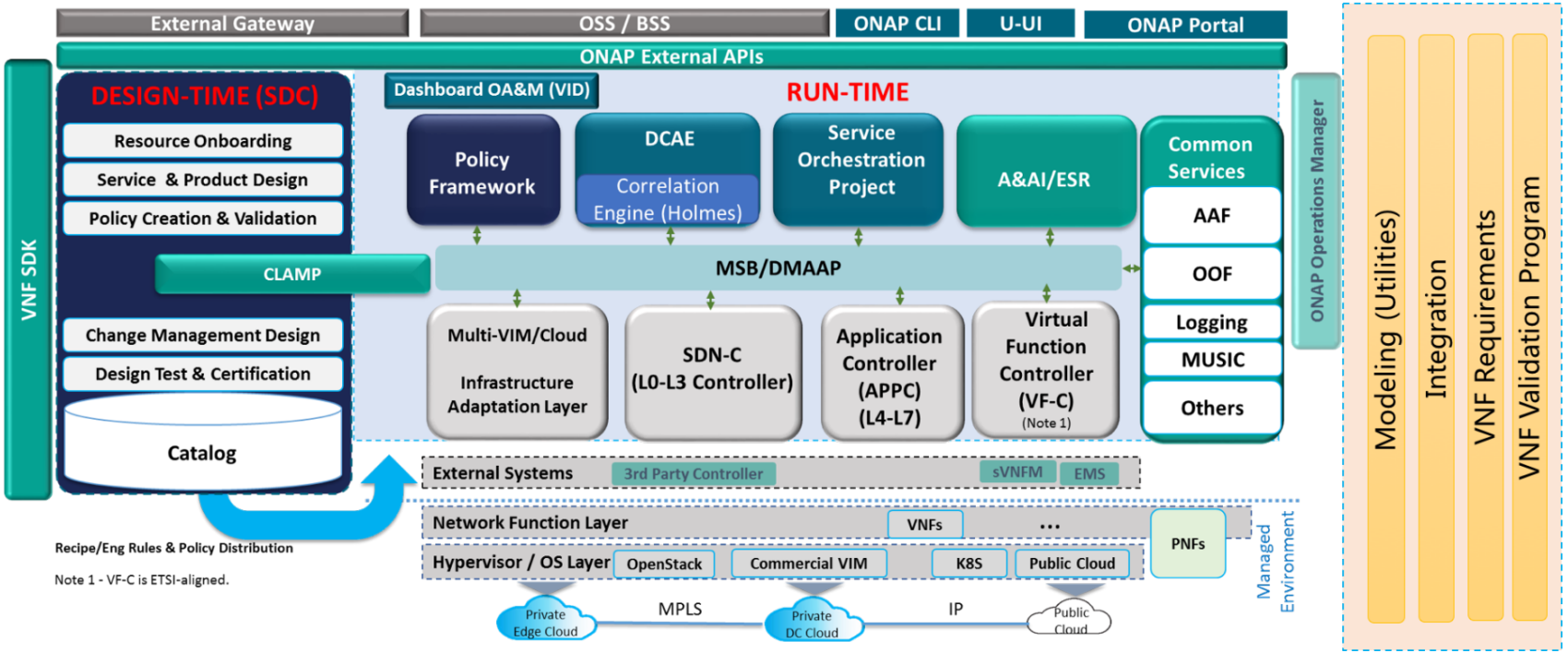
Bikash Koley, The Zero Touch Network, CNSM 2016 Keynote

Juniper's Self-Driving Network



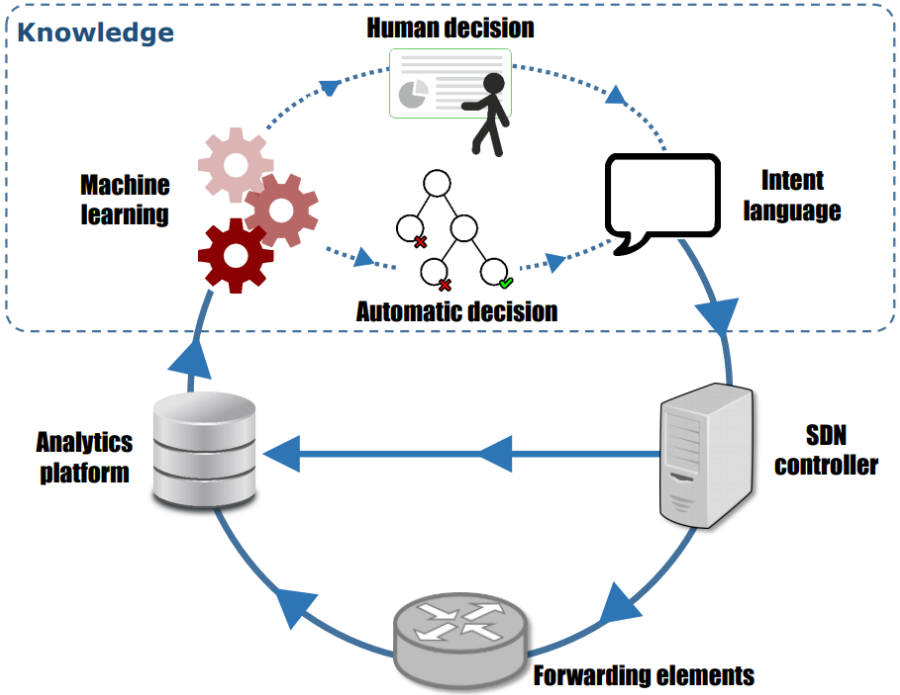
Kompella, Kireeti. "Self-Driving Networks." Emerging Automation Techniques for the Future Internet. IGI Global, 2019. 21-44.

Open Network Automation Platform



https://www.onap.org/platform-2

Knowledge-Defined Networking



A. Mestres, *et al*. Knowledge-Defined Networking. SIGCOMM CCR, 2017, 47:3, 2-10.

Can it Happen this Time?

- The stars are now aligned due to recent technological developments:
  - Network Softwarization
    - Enables flexible monitoring and control of networks
    - Facilitates network-wide optimizations and the deployment of network services on the fly.
  - Machine Learning
    - Enables knowledge extraction from monitoring data and automated decision making
  - Large-scale data processing
    - Enables network data analytics for large and complex networks with many users and applications

Network Softwarization

- Emerging networking paradigm where software controls the treatment of network flows and adds value to these flows by software processing.
- Two expressions of network softwarization:
  - Software-Defined Networking
    - Decouples the network's control and data planes for better programmability
  - Network Function Virtualization
    - Moves packet processing from purpose-built middleboxes to software appliances running on commodity hardware

Machine Learning

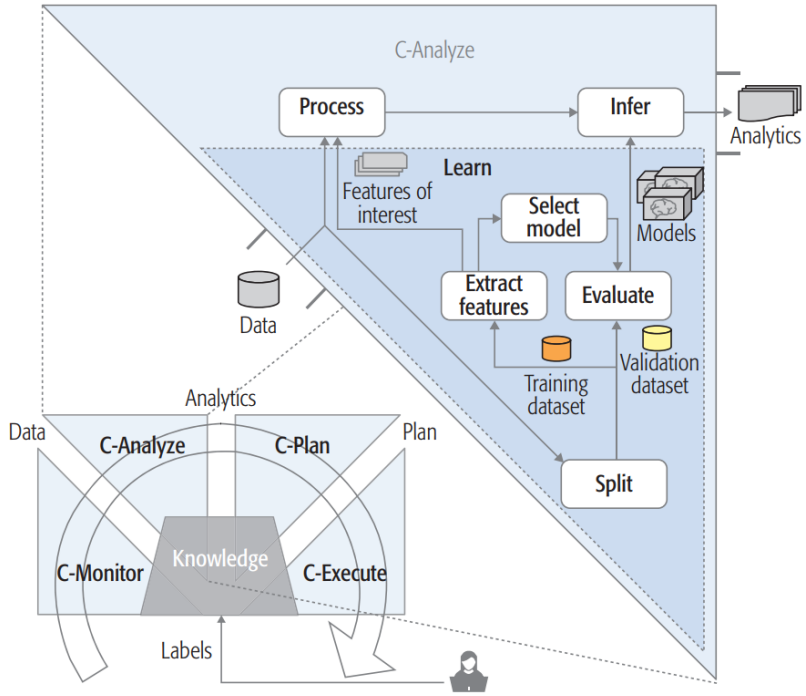
- Knowledge extraction
  - Recent success of Deep Learning
    - image & speech recognition, natural language processing
  - Proliferation of Machine Learning tools
    - TensorFlow, Torch, Keras
  - Availability of large volumes of data (aka Big Data)
- Automated decision making
  - (Deep) Reinforcement Learning has been successful in automating decision making processes
    - cluster resource management, web service configuration, recommendation systems, and robotics

Large-scale Data Processing

- Availability of infrastructure and platforms for data ingestion, storage, and analysis at large-scale
  - Cheap computing and storage
  - Massive parallelization using GPUs
  - Software platforms
    - Spark, Storm, Kafka
- Data processing as a cloud service
  - Amazon EMR, Amazon Kinesis, Azure Stream Analytics

Blue-print of a Cognitive MAPE

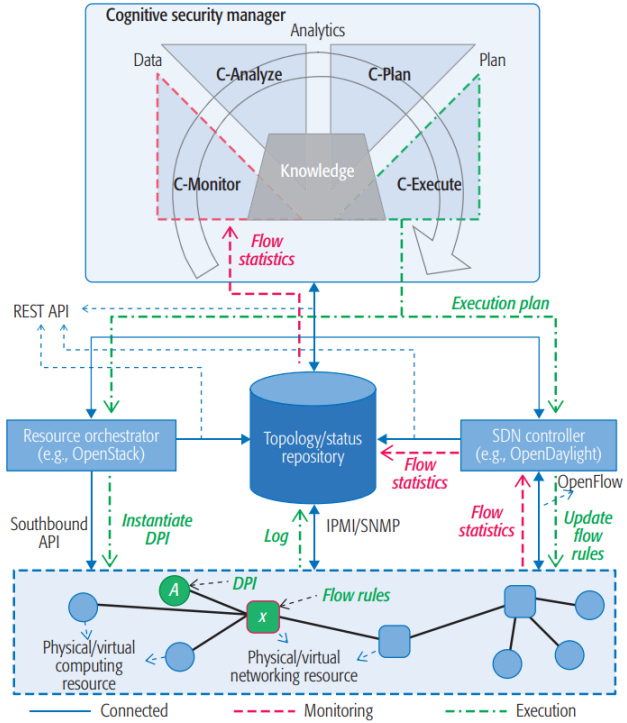
- C-MAPE: Cognitive control loop blue-print for automated network management
- Incorporates ML at each stage
  - *C-Monitor*: performs intelligent probing
  - *C-Analyze*: detects and predicts changes in networks
  - *C-Plan*: automated planning engine to react to changes
  - *C-Execute*: Optimal scheduling for plan execution



S. Ayoubi, N. Limam, M.A. Salahuddin, N. Shahriar, R. Boutaba. Machine Learning for Cognitive Network Management. IEEE Communications Magazine. Vol. 56(1), pp. 158-165, Jan 2018.

Blue-print of a Cognitive MAPE

- Use case: Cognitive Security Manager - Security anomaly detection and mitigation
  - Collects and analyses network statistics to detect security anomalies using ML
  - Uses reinforcement learning to generate a mitigation plan
  - Executes the plan leveraging network softwarization



S. Ayoubi, N. Limam, M.A. Salahuddin, N. Shahriar, R. Boutaba., *et al*. Machine Learning for Cognitive Network Management. IEEE Communications Magazine. Vol. 56(1), pp. 158-165, Jan 2018.

Take-away

- Realizing the long-term vision of automated network management is even more critical today
  - increasing complexity of contemporary networks
  - stringent performance and reliability requirements of emerging applications
- Despite many attempts over the years, technological barriers prevented the realization of autonomous networks
- Stars are now aligned to achieve autonomous networks

Thank you !

Questions ?