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Machine learning for a 5G future

Towards Cognitive Autonomous Networks in 5G

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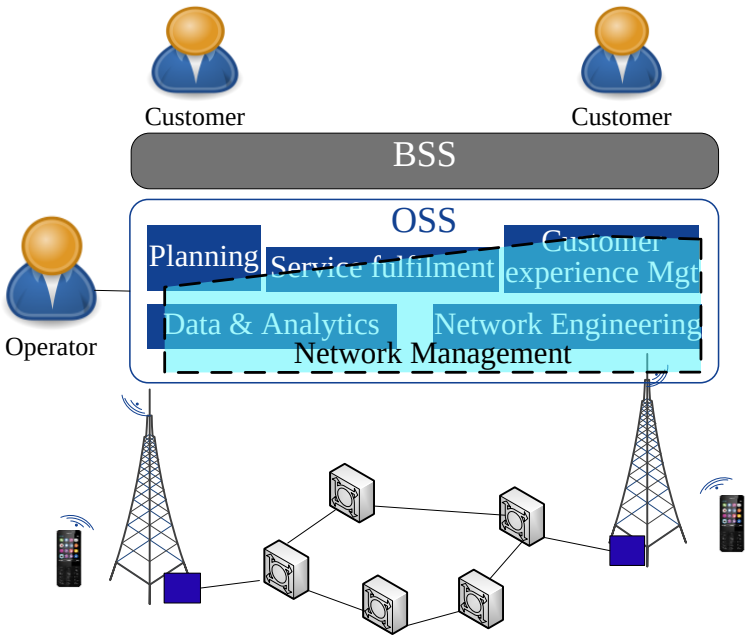
26-28 November
Santa Fe, Argentina

Why is this discussion important?

Need for Cognition in Network Automation

- Multi-RAT/Band Networks → higher complexity, CapEx, OpEx
- Solution = Automation e.g. SON
- SON is inadequate
  - Static, rule-based mapping of KPIs to actions
  - inflexible to the infinitely many contexts



Network Management Automation (NMA) maximizes value of automation

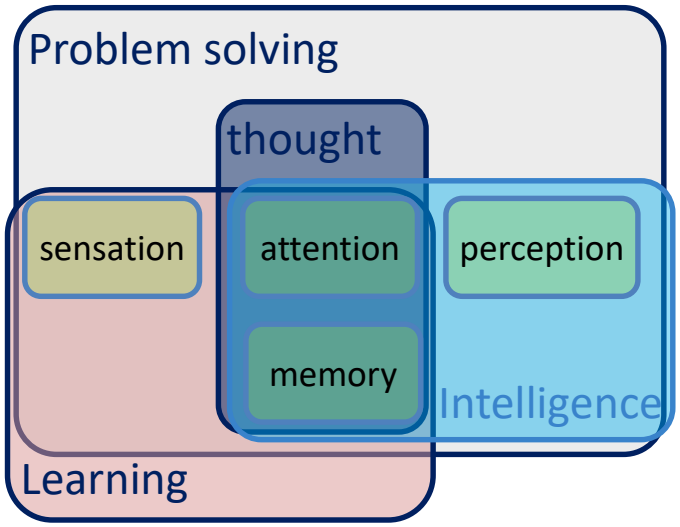
SON - Self-Organizing Networks
KPI - Key Performance Indicator

But what is Cognition?

Automation, self-organization and cognition

- Nature motivates Self-Organization
  - E.g. insect colonies on foraging for food
  - Non-deterministic self-organization - ".. foraging … is also a learning process." [6].
  - Behavior emerges from internal cognitive process

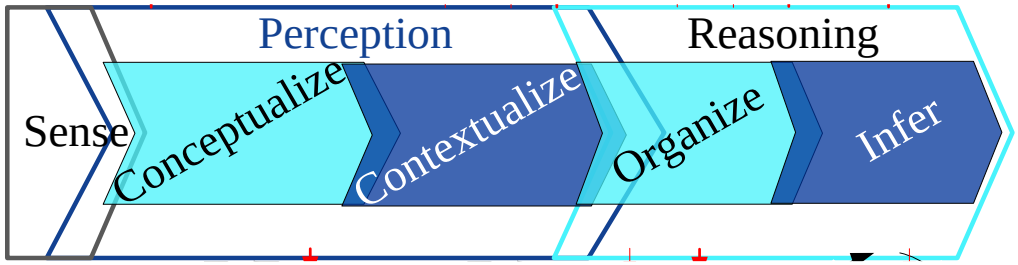
- Cognition (in humans): the collection of mental sub-processes to support acquisition of knowledge and understanding through sensory stimuli, experience and thought



Four basic processes as core;
Higher processes as combinations of basic and other higher processes

How then should cognition be modelled?

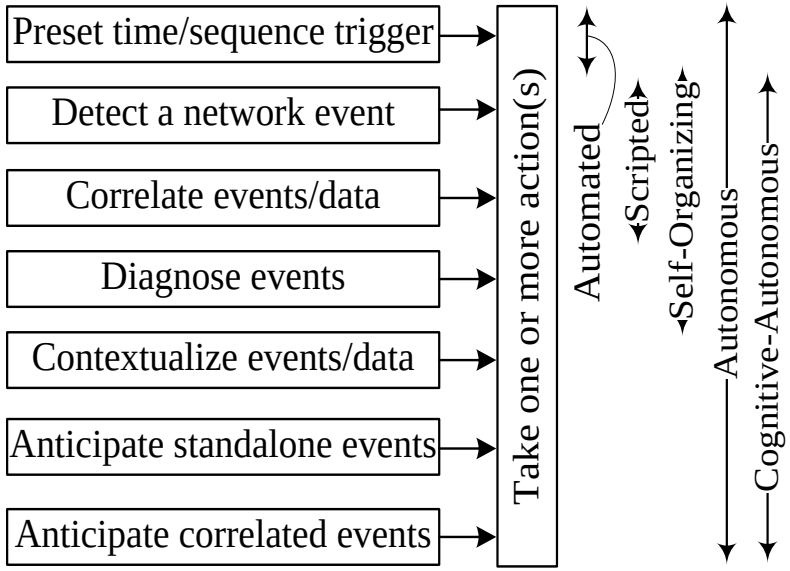
Cognition: A perception-reasoning pipeline



What levels of automation can be achieved in networks?

Taxonomy -

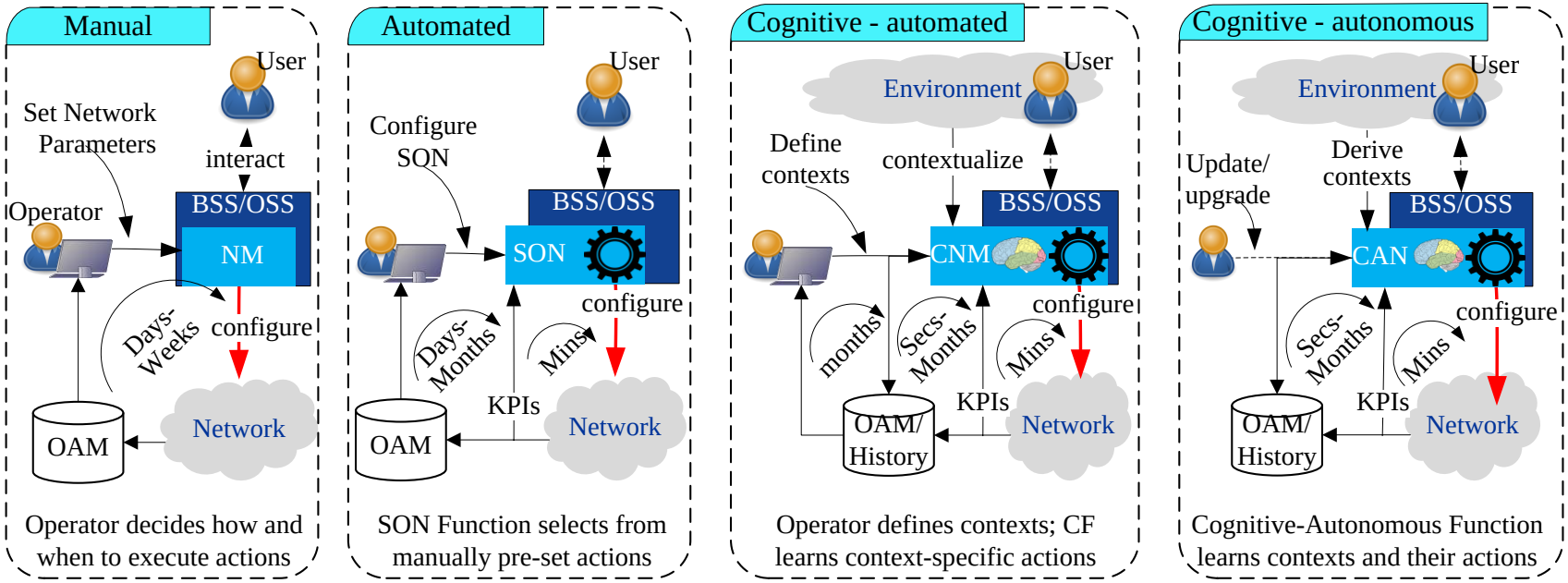
- Two dimensions – decision & action
  - Scripted network – human-controlled scenario specific execution of scripts
  - Self-Organizing Network – **automatically** interprets events to determine cause-effect relations, selects and executes of actions
  - Autonomous network - acts on its own, but may not be able to reason suitably
  - Cognitive network - reasons to formulate decision/actions, although actions may require operator approval before execution



Different capabilities are achieved by the different form of automation

How do we get to CANs?

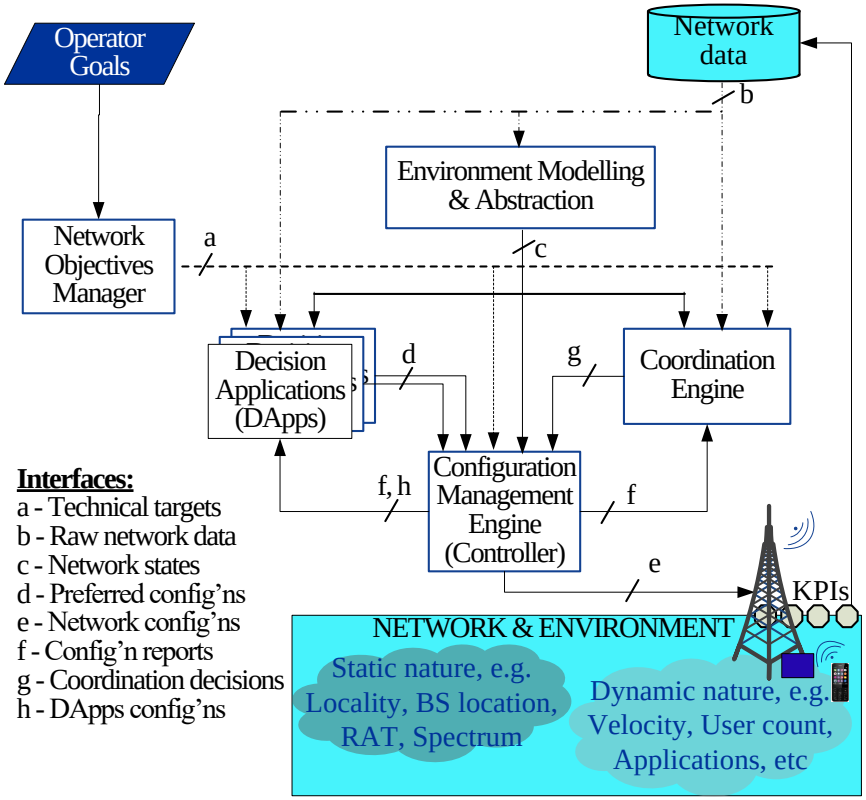
Transition trajectory towards CANs



How will the CAN system look like?

CAN Framework

- Cognitive Function (CF) may contain:
  - DApps - Learners for specific objectives
  - CME (controller) - set boundaries and decide if recommendation is executed
  - CE - resolve conflicts among DApps recommendations
  - EMA - define and label observed network events and contexts
  - NOM - translate the operator's goals to technical targets for CFs



Can we concretize these ideas?

Example CF – Mobility Robustness

- Objective: learn optimal behavior per mobility (velocity) state in cell
  - Control - Hysteresis (Hys) & Time-to-Trigger (TTT)
- KPIs – Rates of
  - HO Ping-Pongs (PPR)
  - RLF due to early HO (FER)
  - RLF due to late HO (FLR)
- Scenario: LTE network of 21 cells
  - Velocity: 3,10,30,60,90,120 kmph

- Implementation – Supervised learning on Velocity, Hys, TTT and rates
  - Nearest Neighbors Regression (KNN)
  - Decision Trees (DT)
  - Random Forests (RFR)
  - Extremely Randomized Trees (ETR)
- Evaluation: RE - absolute error relative to expectation of rate E{y}

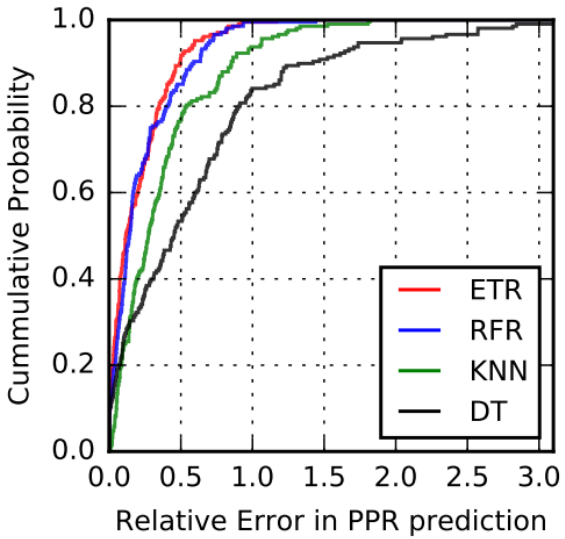
$$RE = \frac{|y_i - \hat{y}_i|}{E\{y\}}$$

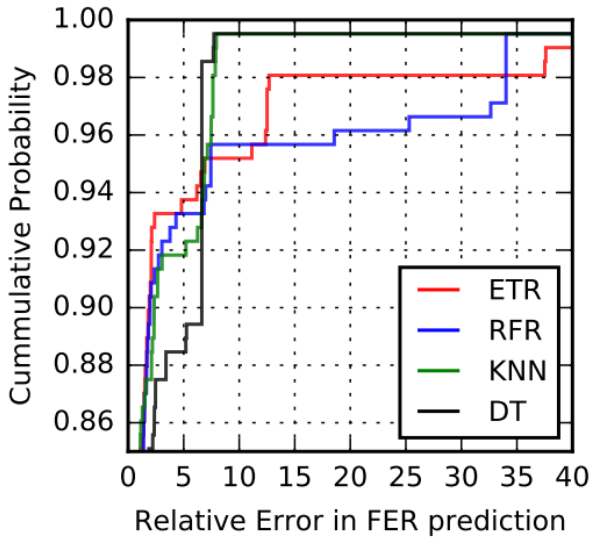
HO: handover; RLF: Radio Link Failures

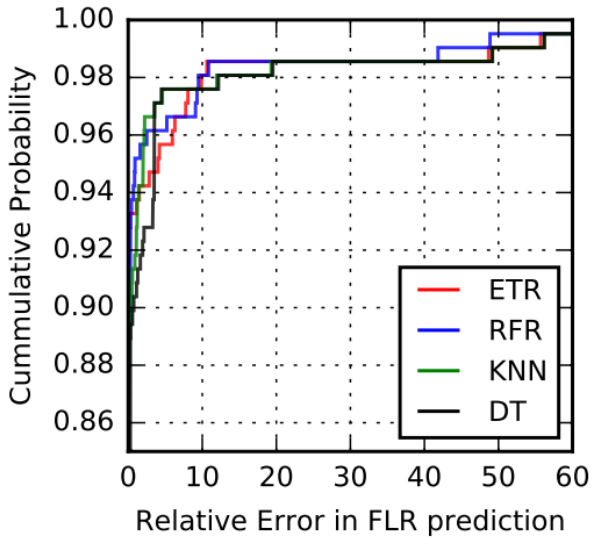
What has been observed so far?

Learning network response

ML algorithms predict behavior in unknown states using response in known states



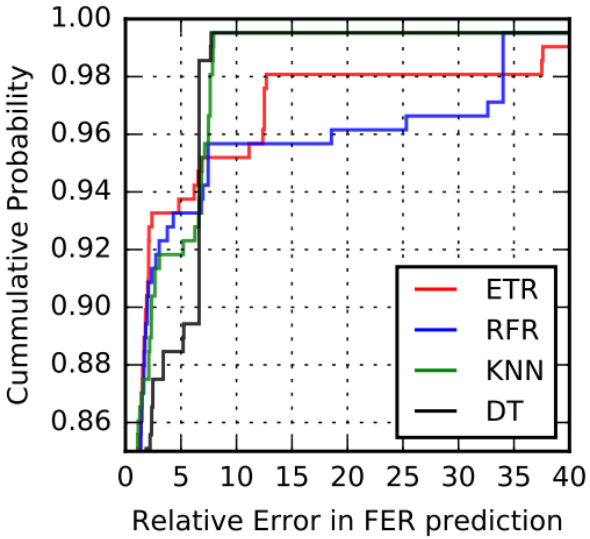


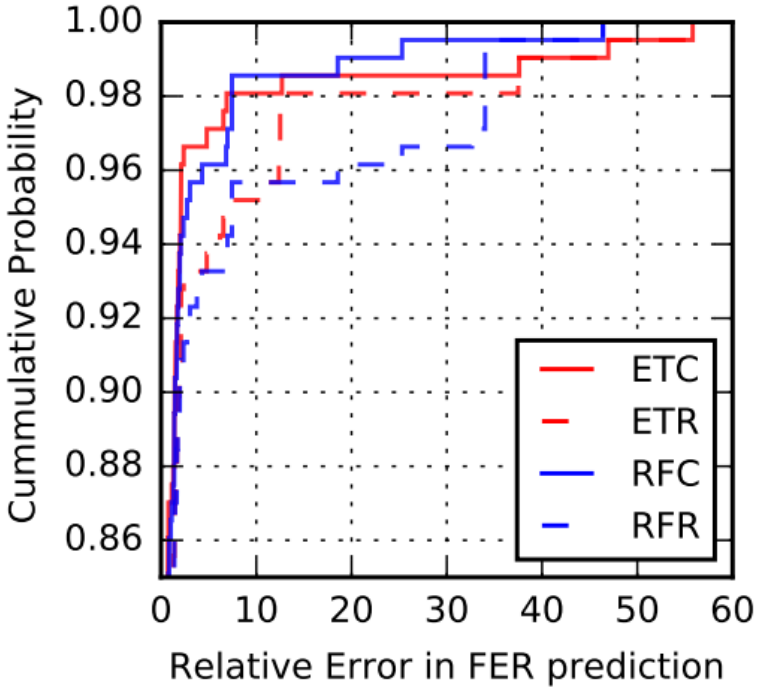


Any lessons from the study?

Not simply off the shelf

Achieve better outcomes through smart combinations of algorithms





Learning methods can automate network management not only to learn the best configurations for specific states but also the underlying network response which can then be used to predict response in unknown states

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Thank you