Twinning Networks

On the Use and Challenges of Network Digital Twins

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Replication in the Digital Era

- Digital twins are digital replications of physical entities that enable data to be seamlessly transmitted between the physical and virtual worlds
  - Facilitate the means to monitor, understand, and optimize the functions of the replicated entities
- Originally applied in manufacturing industry processes and machinery
- Main elements
  - Sensors and actuators, so that digital twins can replicate the real twin behavior
  - AI, in order to make fast and intelligent decisions on behalf of their real twin.
  - Communication, to interact in near real time with the environment, real twins, and/or other digital twins
  - Representation, from a 3D avatar to a graphical dashboard, depending on the application domain
  - Trust, for real twins to trust their digital twin
  - Privacy and security, including the resolution of regulatory and political issues
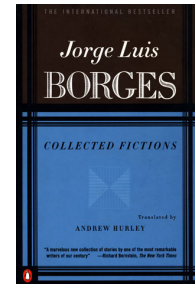
Borges' Exactitude Paradox

- The native complexity of networks has made more difficult DT application
  - o Metcalfe's law
  - o Laser effect(s)
  - o The invariants: topology, conservation, openness
- And more desirable their use
  - o 5G foresees a x10 densification of sites compared to 4G
  - o Best user experience demands heterogeneity in access technologies
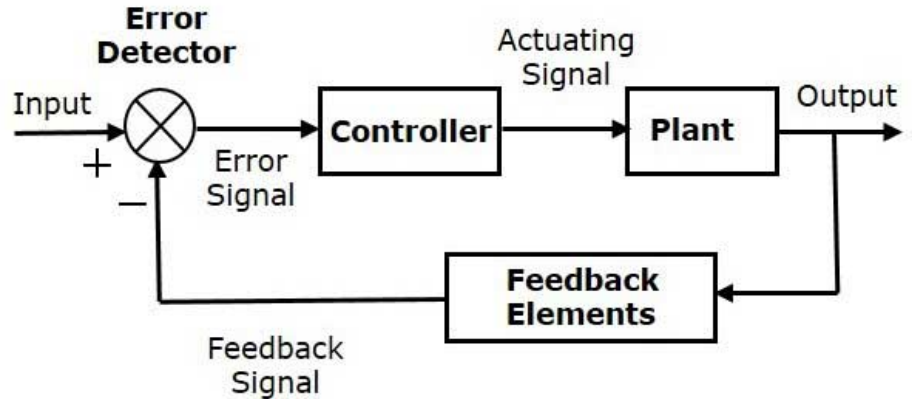 - o The continuous challenge of centralized proposals, way beyond the usual OTT

…In that Empire, the Art of Cartography attained such Perfection that the map of a single Province occupied the entirety of a City, and the map of the Empire, the entirety of a Province. In time, those Unconscionable Maps no longer satisfied, and the Cartographers Guilds struck a Map of the Empire whose size was that of the Empire, and which coincided point for point with it…

—Suarez Miranda, *Viajes de varones prudentes*, Libro IV, Cap. XLV, Lerida, 1658

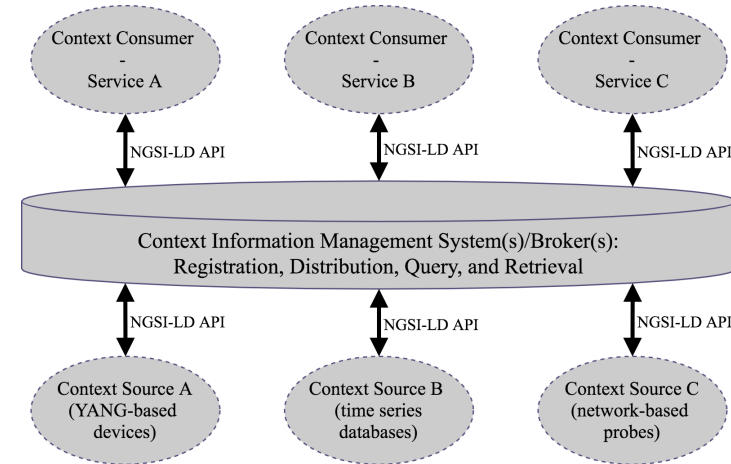**#RECONECTA**

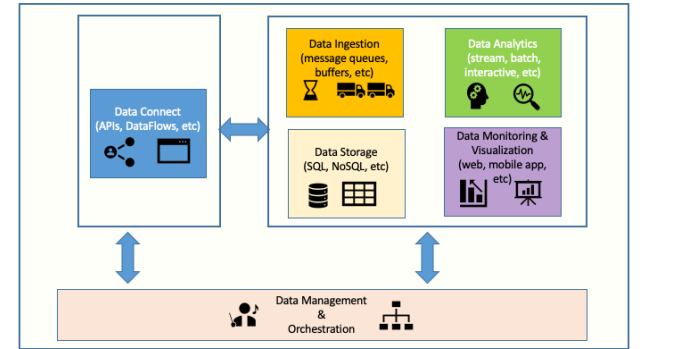*Telefónica*

Automatics 101

- Automatics have been around for a long time
  - AI as a tool to derive further insights from data and improve policies
  - Extended capabilities, but we should not expect Skynet
- Beware the network differential facts
  - Topology (and geometry!) awareness
  - The conservation principle
  - Openness
  - Integrity and auditability
  - Isolation

- Model obliviousness
- Flows and architectures
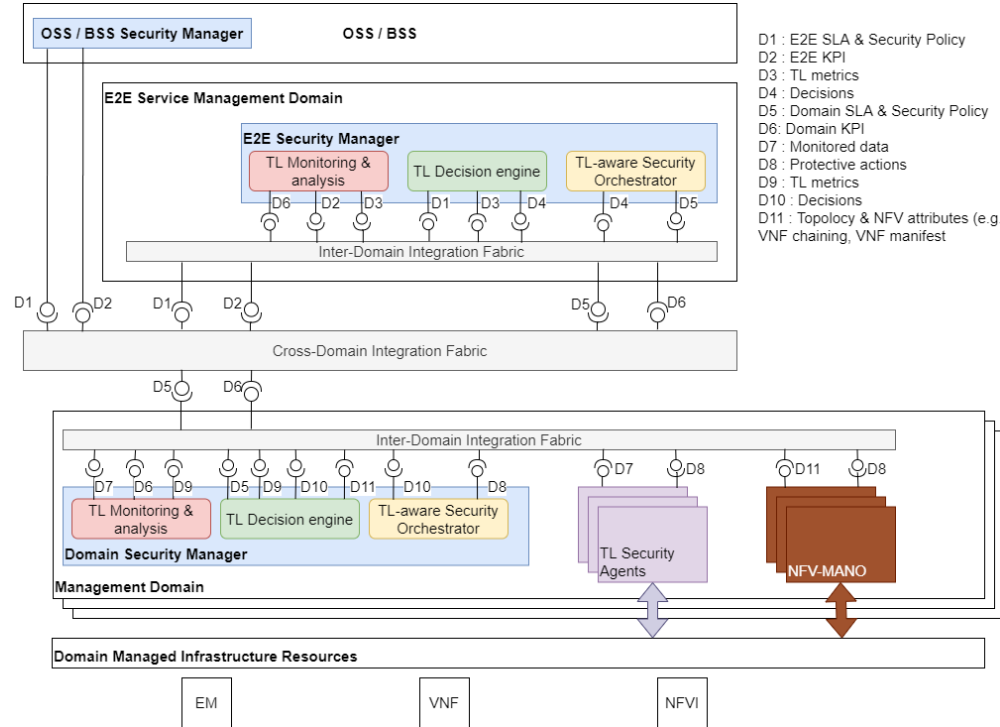- Software network abstractions as essential enablers

The Data Flow

- No matter how intelligent: Crap in means crap out
  - Usable: Adaptation (formats, scales…)
  - Sufficient: Topology (sources, aggregators…)
  - Safe: Provenance (origin, timestamps…)
  - Steady: Continuity (pace, availability…)
- Deal with heterogeneity
  - At all levels: sources, consumers, models, deployment styles, supporting infrastructures
- An enhanced data fabric seems the logical approach
  - Combining current network monitoring tools and recent telemetry developments
  - Metadata becomes essential, including semantic mappings
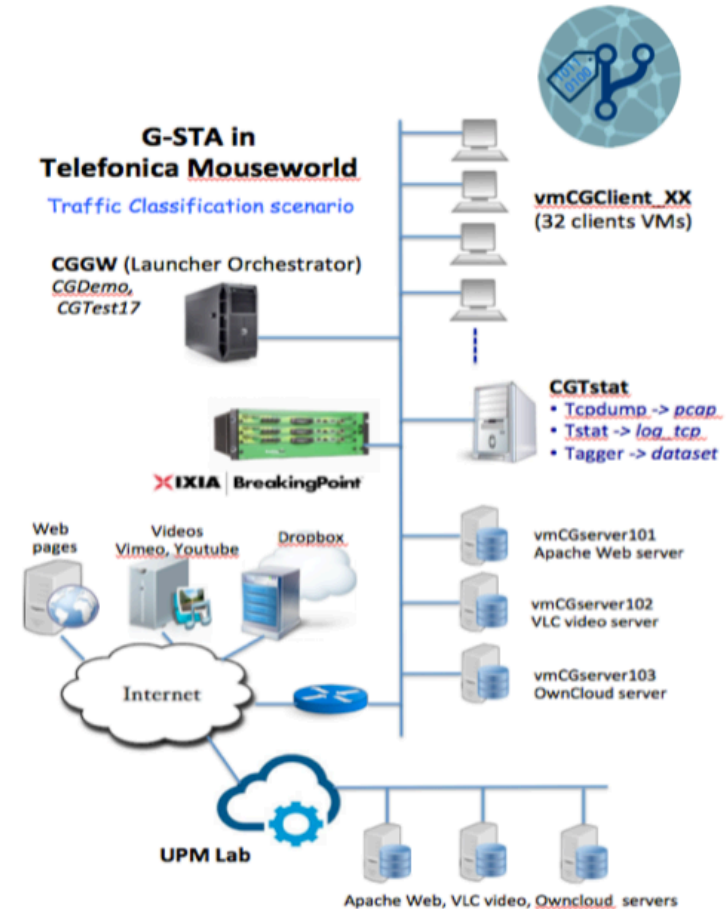 - A data stream ontology, not that far away

The Action Flow

- Heterogeneity at its best
  - OAM actions at a wide variety of different domains
- Initial strategies in network management
  - Domain specific
  - Recommendation systems
  - Autonomic protocols
- SBA approaches and capability models
  - Abstractions of element functionalities
  - Usable as building blocks
  - Compositional models
  - Inter-domain collaboration for E2E
  - Registration and discovery mechanisms

INSPIRE-5Gplus

D1 : E2E SLA & Security Policy
D2 : E2E KPI
D3 : TL metrics
D4 : Decisions
D5 : Domain SLA & Security Policy
D6: Domain KPI
D7 : Monitored data
D8 : Protective actions
D9 : TL metrics
D10 : Decisions
D11 : Topolocy & NFV attributes (e.g. VNF chaining, VNF manifest
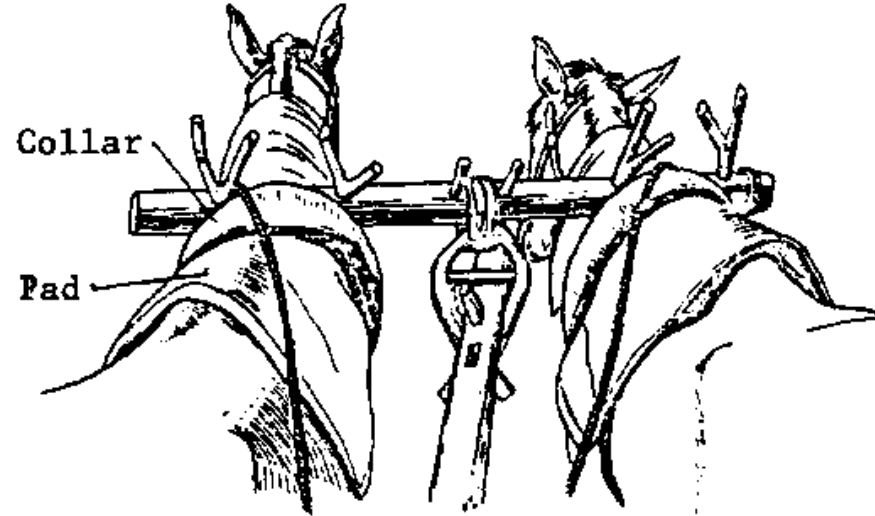
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The *Mouseworld*, a First Step

- Originally conceived as an environment for security experimentation
  - Later applied to AI/ML training and validation
  - Suitable to evolve into a network digital twin
- Able to incorporate applications, functions and topologies
  - Virtualized network functions
  - Emulators of physical network functions
  - Traffic traces (network data) to be injected.
- Using a model-based approach
  - Simple reconfiguration
  - Differential analysis of alternate scenarios
- Not totally there yet
  - Real-time data ingestion
  - Integration with online data analytics
  - Direct control actions

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An Essential Tool for Harnessing AI in Networks

- Lower the cost of network optimization
  - Optimized decision making
- Safer assessment of innovative network capabilities
  - DevOps-oriented certification
  - Network fuzzing
- Customize network operation training
  - Human, ML systems and their combinations
- Privacy and regulatory compliance
  - Top-grade anonymization

Collar

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