

Herding Dopplegangers On the Flows to Enable and Apply Network Digital Twins

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Digital Lookalikes

- 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
 - \circ $\,$ Sensors and actuators, so that digital twins can replicate the real twin behavior
 - Al, 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
 - o 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
 - Metcalfe's law
 - Laser effect(s)
 - The invariants: topology, conservation, openness
- And more desirable their use
 - 5G foresees a x10 densification of sites compared to 4G
 - Best user experience demands heterogeneity in access technologies
 - The continuous challenge of centralized proposals, way beyond the usual OTT
- Software network technologies have become an essential enabler
 - Essential abstractions at all network elements
 - Feedback, input, detection, actuation

...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







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...)
- An enhanced data fabric seems the logical approach
 - Supporting resource, orchestration and function sources
 - Combining current network monitoring tools and recent telemetry developments





The Data Aggregation Scenario



- □ Support the integration of different data flows
 - Open
 - Automated
 - Secure
 - Scalable
- Deal with heterogeneity at all levels
 - Data sources
 - Data models
 - Deployment styles
 - Supporting infrastructures
- Not just data
 - Metadata becomes essential, including semantic mappings
 - What seems to claim for a data stream ontology
 - Not that far away: data modeling is a first step



The Action Flow

- OAM actions at a wide variety of different domains
 - o Challenging, given the current state-of-the-art
- Initial strategies
 - o Domain specific
 - Recommendation systems
 - Autonomic protocols
- SBA approaches and capability models
 - Reusable functionality description
 - Abstractions of network element functionalities usable as building blocks
 - Combined to provide more powerful features
 - Registration mechanisms to support CI/CD
 - Inter-domain collaboration for E2E management





Multi-Domain Capability-Based Security



- Each domain exposes a series of capabilities
- Consumed by other domains
 - ➡ Including the E2E layer
- More a choreography than an orchestration
- Emerging standards
 - ➡ ETSI NFV SEC architecture
 - ETSI ZSM framework
 - ➡ IETF I2NSF models



Automatics 101

- The crucial component in any closed loop is the control input
 - o Specially in complex systems
 - \circ $\,$ Including the human in the loop $\,$
- *Intent* is the common name for abstracting the control input
 - o Base model
 - Language and expressions
 - o Interpretation
 - Composition and conflict resolutions
 - Security: trust and privacy concerns



- Audit track and intelligibility
 - The who, the what, the when
 - o And the why







Trusted Data in Support of Intent

- A common platform available at each participating domain
 - Based on service meshes for elasticity
 - Operational data lakes for service discovery, brokering and SLA monitoring
 - DLTs and Smart Contracts for auditability, licensing and disintermediated trading
 - Trusted Execution Environment to support trust without privacy loss
- An intent-based API
 - For interacting with the platform
 - Available to all stakeholders: users and/or providers
 - Dynamic composition of resources



The Mouseworld, a First Step



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





There Are Worse Things to Herd

This document has been produced in the course of 5G-CLARITY Project. The research leading to these results received funding from the European Commission H2020 Programme under grant agreement No. H2020-871428. All information in this document is provided "as is", there is no guarantee that the information is fit for any particular purpose. The user thereof uses the information at its own risk and liability. For the avoidance of all doubts, the European Commission has no liability in respect of this document, which is merely representing the authors view.



The research conducted by INSPIRE-5Gplus receives funding from the European Commission H2020 programme under Grant Agreement N° 871808. The European Commission has no responsibility for the content of this presentation.







