IEEE Future NETWORKS

Enabling 5G and Beyond

INGR

International Network Generations Roadmap (INGR)

Systems Optimization Working Group

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IEEE

International Network Generations Roadmap (INGR)

Future network technologies (5G, 6G, etc.) are expected to enable fundamentally new applications that will transform the way humanity lives, works, and engages with its environment.

- The INGR is a semi-annual technical document highlighting network technology evolutions over 3-, 5- and 10-year horizons.
- Created by a group of 100+ international IEEE experts from industry, academia and prominent research labs, organized across 15 distinct working groups.
- Every 12-18 months, INGR releases a new multi-chapter document highlighting development needs, the challenges/roadblocks to achieving those needs, and potential solutions to those challenges.
- At least twice a year, INGR leadership does outreach to industry and holds presentations highlighting the most crucial future technical roadblocks, to engage industry to solve or avoid those risks and roadblocks.

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IEEE INGR Structure and Working Groups

CATEGORY	DESCRIPTION	INGR WORKING GROUP CHAPTERS
Access	Describes how the users are able to reach the network	• Massive MIMO • mmWave and Signal Processing • Energy Efficiency
Networks	Describes how the networks are interconnected	• Edge Services • Satellites • Optics
System and Standards	Describes system standards and testability	• Standardization Building Blocks • Testbed • ***Systems Optimization***
Enablers and Users	Represents all the elements that enable deployment, assure functionality and security and address impact on society and environment	• Deployment • Applications and Services • Security and Privacy • Artificial Intelligence and Machine Learning (AI/ML) • Connecting the Unconnected (CTU)

SysOpt WG Scope

The Systems Optimization working group within the IEEE Future Networks Initiative addresses:

- modeling of control of complex networks of self-organizing systems
- identification of the key problems for control of such networks
- development of new solutions to achieve network self-organization
- collaboration between the industry and standards communities

Some of the INGR groups we work with:

- AI/ML, Energy Efficiency, Security, Standards Building Blocks and Testbed

Roadmap Chapter on Systems Optimization:

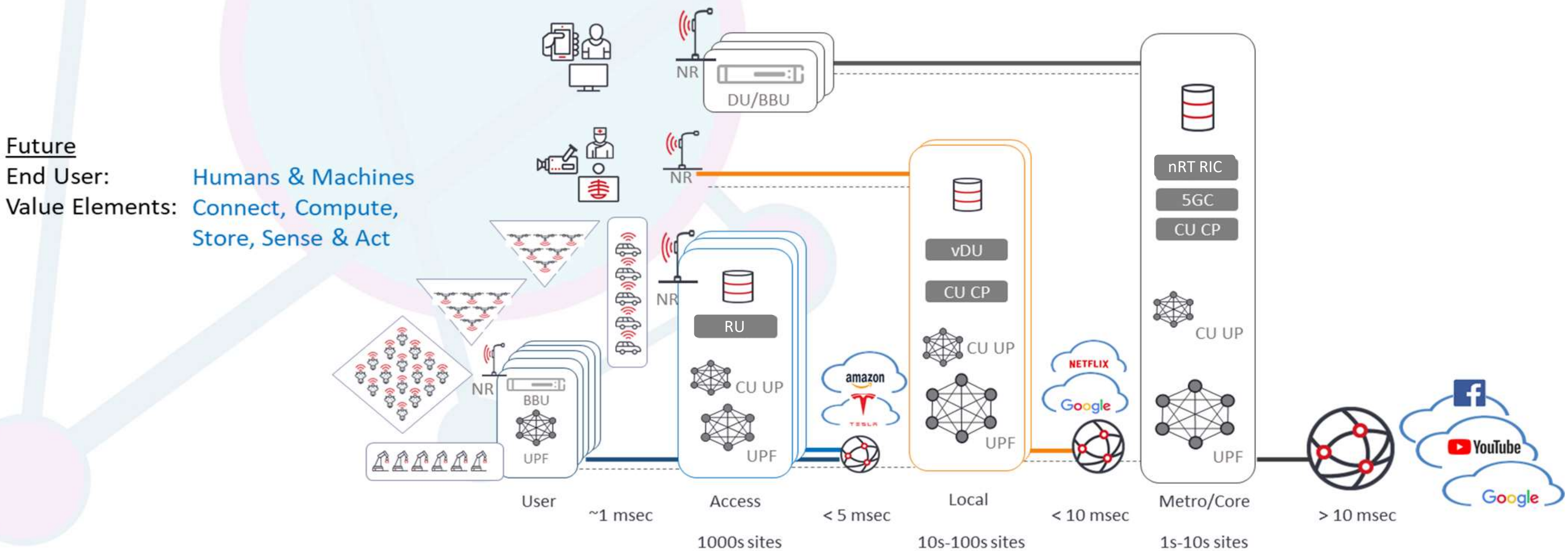
- https://futurenetworks.ieee.org/images/files/pdf/INGR-2022-Edition/IEEE_INGR_SysOpt_Chapter_2022-Edition-Preview.pdf

Evaluating Future Demands

- Service and Traffic Variance in 5G/6G
  - mMTC: high latency/low individual traffic/many sources
  - eMBB: low to high latency/high traffic
  - URLLC: low latency/low traffic;
- Control Variance
  - Centralized: higher latency/lower cost/greater resources
  - Distributed: lower latency/higher cost/limited resources
  - Spread of intelligent systems capable of autonomous action

Projecting Future Landscape

- Increasingly used for machine-to-machine applications
- More complex systems architecture/optimization



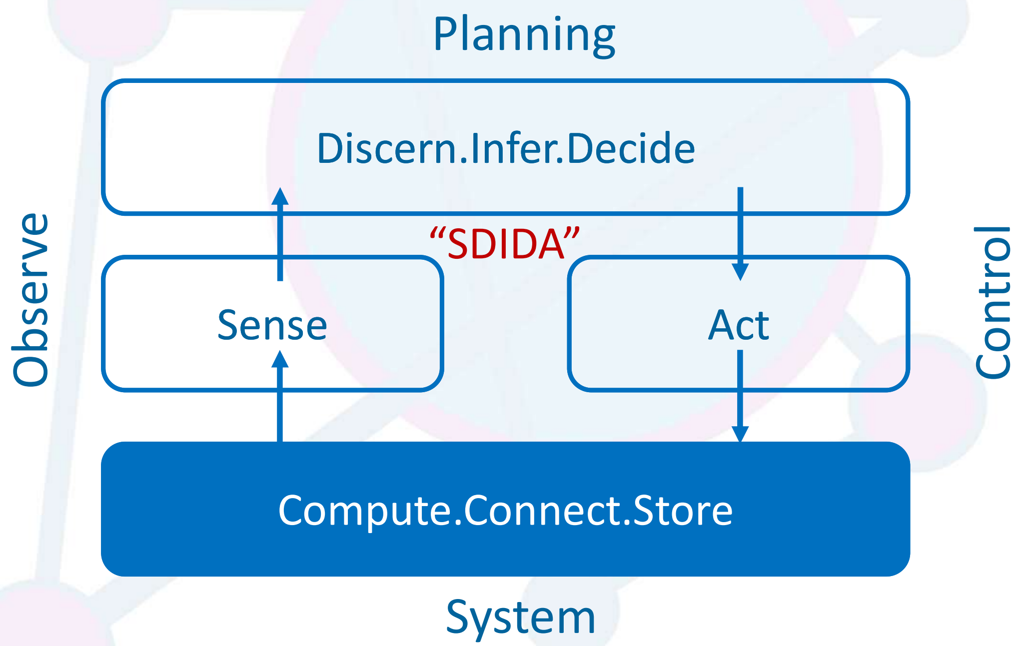
10-year Projection

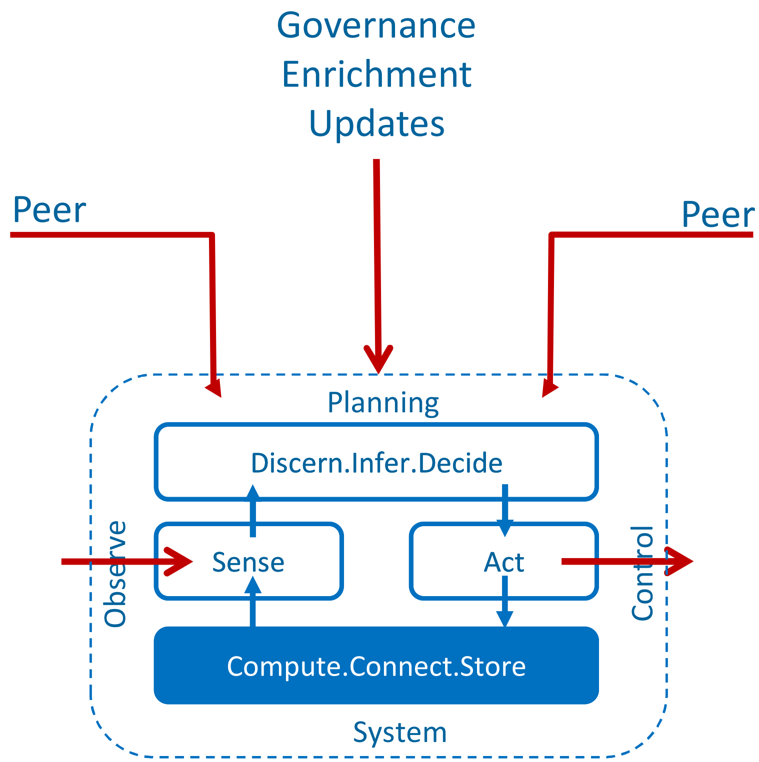
Future systems will be highly distributed fabrics of compute, intelligence and networking interconnected at multiple levels, making optimization a challenge.

Key areas of need:

- Dynamic fabric allocation with (near) real time discovery and peering of heterogenous resources contributed by disparate providers
- Dynamic semantics discovery and negotiation at points of attachment between peer entities
- Distribution and federation of intelligence across disparate contributing entities
- Self-optimizing techniques for autonomic system behaviors

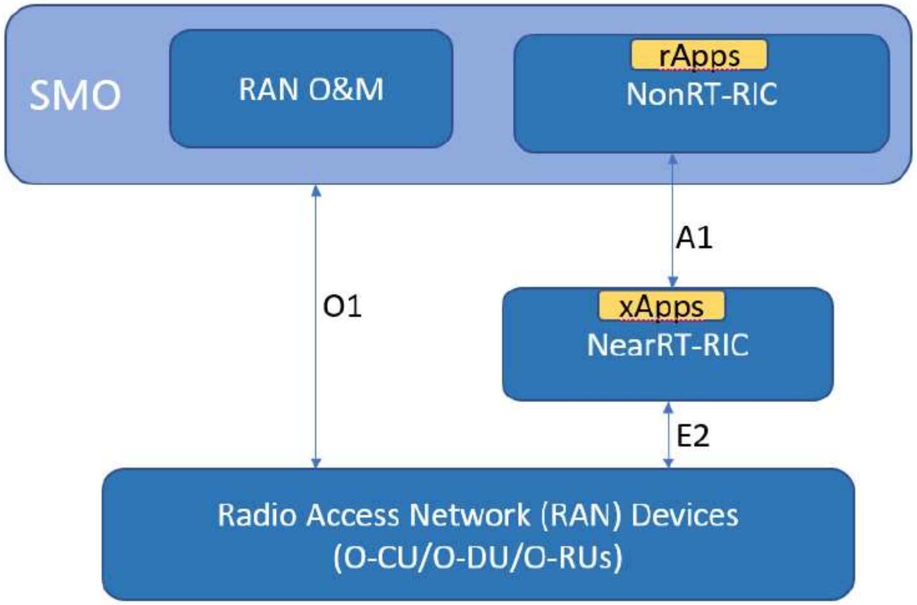
System Intelligence Model





O-RAN Use Cases: Hierarchical, Distributed, Open & Heterogeneous RAN Optimization

- O1 Interface
  - Traditional network operations and telemetry
- A1 Interface
  - Provides policy direction from Non-Real Time RAN Intelligent Controller to Near-Real Time RAN Intelligent Controller
  - Also can provide enrichment information
- E2 Interface
  - Supports RAN device control and reporting of kpi to Near-RT RIC



Source: Dilip Krishnaswamy (dilip@ieee.org)

RAN Intelligent Controller

Non-RT RIC

- Monitor long-term trends and patterns
  - E.g., RAN slice subnets' performance, and
- Gather external enrichment information
  - E.g., climate information, flight area restrictions, space load information
- Construct and train AI/ML models to be deployed in RAN
- Non-RT RIC runs "rApps", enabling non-real-time control and optimization of RAN elements and resources and policy-based guidance to Near-RT RIC apps
- Control loops on the order of 1s or more

Near-RT RIC

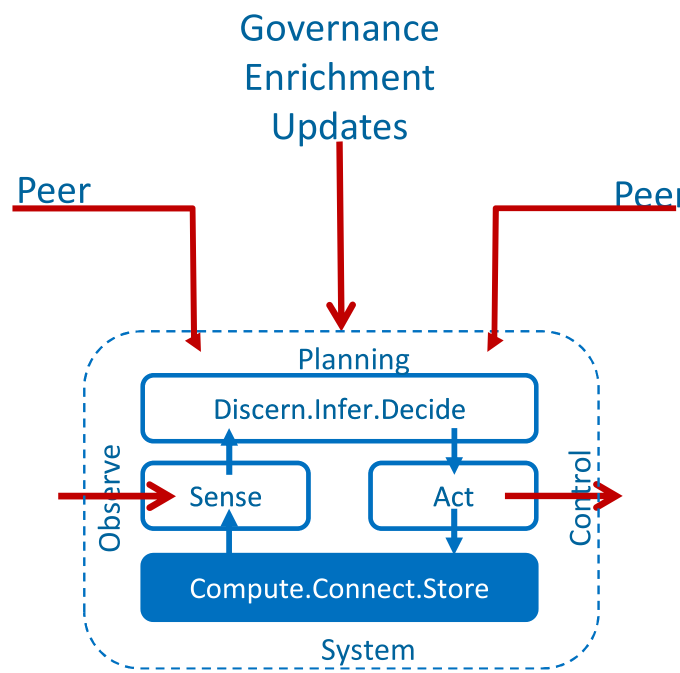
- Execute deployed AI/ML models (e.g., prediction) and other "xApps" (e.g., positioning, resource allocation) supporting near-real time control
- Takes into account
  - O1 configuration (e.g. static RRM policies)
  - Policies received over A1 from Non-RT RIC, and
  - E2 measurements received from the E2-Node Network Functions
- Control loops on the order of 10ms-1s

O-RAN rApp/xApp Use Cases

- Network Slice Performance Optimization
- Virtual RAN sharing
- Local Indoor Positioning
- Context-based Dynamic Handover Mgmt for V2X
- Flight Path Based Dynamic UAV Resource Allocation
- Energy Savings

Use Case: Inter-System Coordination in the Aggregate

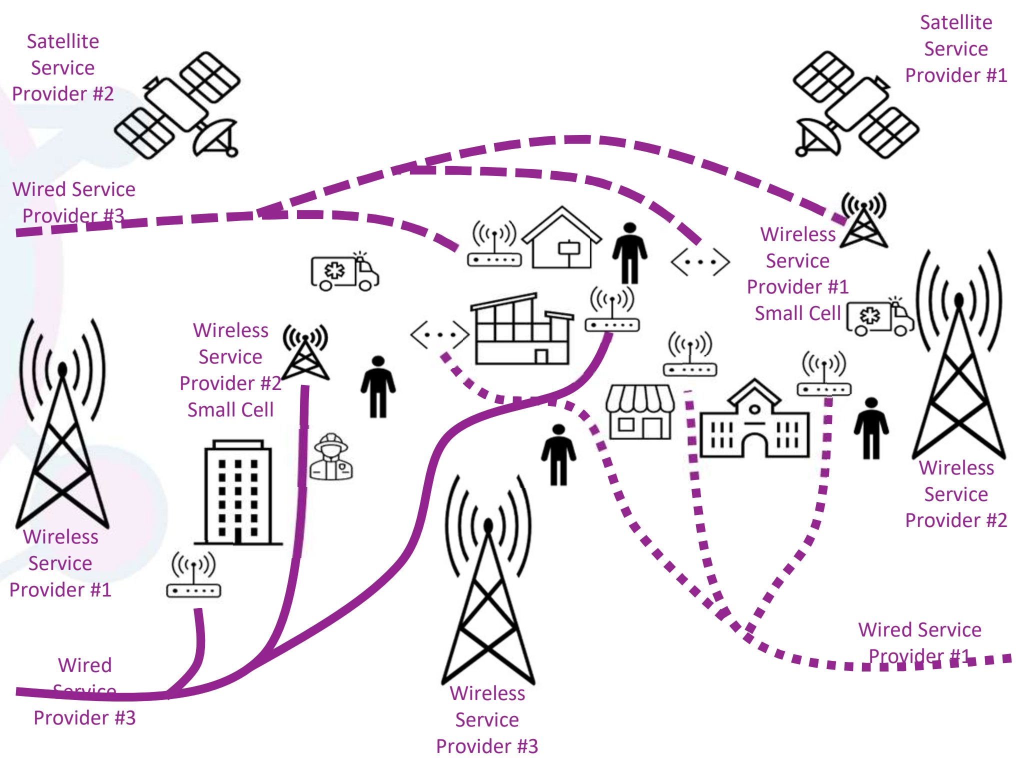
- Recall
  - Cross-domain federation, cross-domain coordination as a SysOpt future issue
- This part focuses on “peer” inputs to optimization planning
- Optimization planning cycle
  - Multiple cycles
  - Different scopes
  - Different time scales
  - Different degrees of automation



Source: Baw Chng (baw@bawman.com)

Base Scenario

- Simplified depiction of a fairly typical deployment scenario
- Multiple communications service providers serving an overlapping geographical area
- Multiple communications technologies serving an overlapping group of end-users



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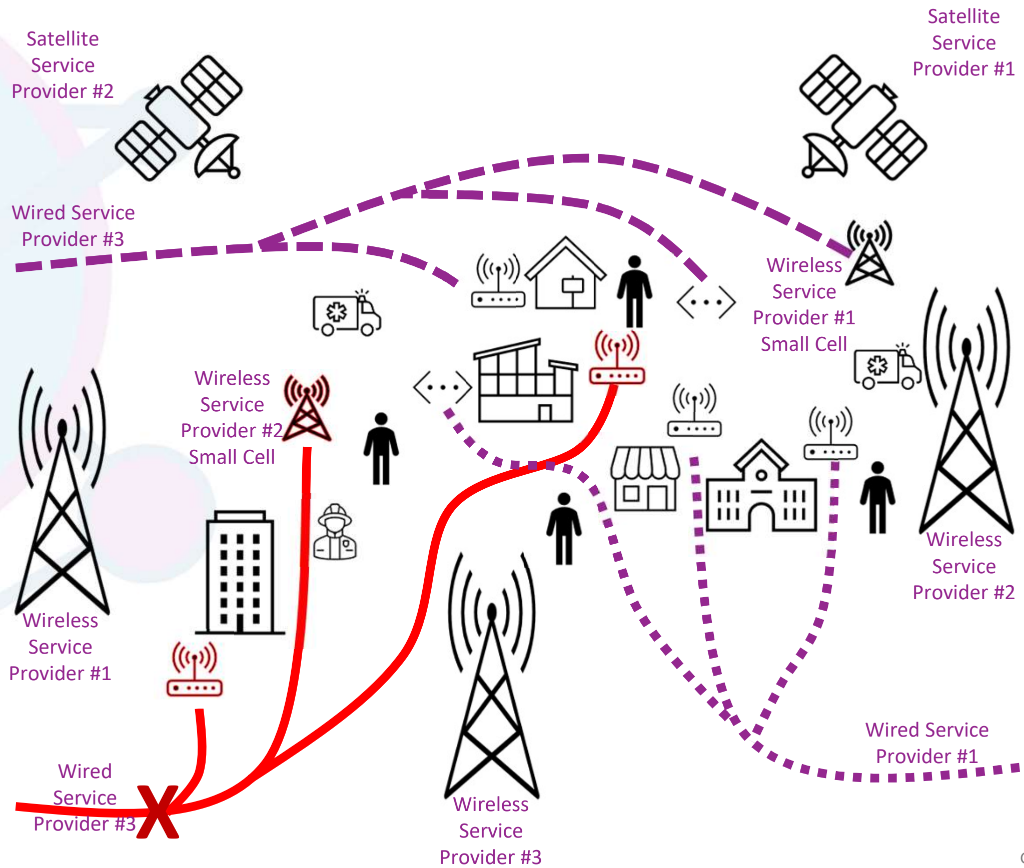
Motivation and Use Case

Salient point

- When one network/system degrades or fails, users switch over to other networks/systems
  - Potentially large number of users switch networks/systems in short order
  - The switch overs may be uncontrolled
  - Networks/systems the users flee to may be overwhelmed by the "surge"
- ***What if networks/systems can learn ahead of time that one of its neighboring network/system is degrading or is about to fail?***
  - *Gives the target networks/systems opportunity to spin up additional resources to deal with the "surge"*

Gap

Standards for inter-system coordination ***in the aggregate***



Identifying Needs in 10-year Vision

	Future State 10-years
Need #1	Dynamic discovery and peering between heterogeneous intelligent systems Communication of intents/capabilities between heterogeneous intelligent systems
Need #2	Distributed dynamic resource allocation, optimization and monetization across autonomic systems
Need #3	Self-organization of federated domains
Need #4	Federation/integration across public/private boundaries
Need #5	Modeling and tooling to identify dependencies, potential deadlocks and predict/optimize system performance
Need #6	Testbeds suitable for testing systems optimization strategies, especially interactions such as AI/ML governance and federation

Details can be found in the SysOpt Roadmap chapter

Analysis of Standards and Future Directions

- ETSI GANA (Generic Autonomic Network Architecture)
  - Addresses similar model with governance needs
  - Looking into possible enhancements such as
    - Incorporation of the SDIDA model
    - development of mechanisms for auto-discovery and federation
    - development of brokers to support federation of domains
- TMF Multi-SDO Initiative
  - Development of Common Operational Principles for Autonomic/Autonomous Networks
    - Establishing requirements for interaction/governance by human operators and interaction between peer autonomous networks/systems

Thank You

- Questions and Answers, Discussion …