NETWORLD EUROPE

Strategic Research and Innovation Agenda Webinar
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SYSTEM ARCHITECTURE

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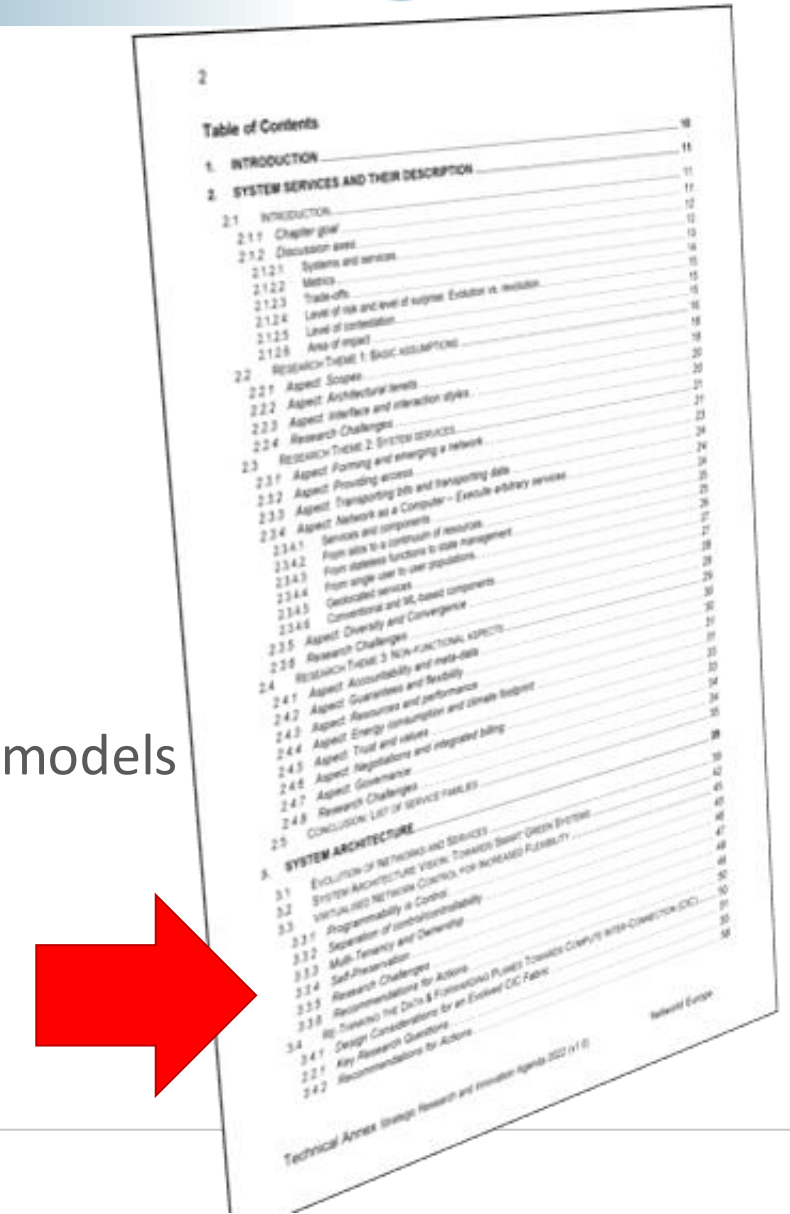
ADMINISTRATIVE OVERVIEW

OVERVIEW

- SRIA2022 Tech. Annex - System Architecture section (pp. 39-84)
  - Originated at VFCS 2017 and in SRIA 2018 as Network Architecture
  - Substantially extended to a System Arch in the SRIA 2020 version
    - Basis for System Architecture in 6GIA European industry 6G Vision WP
    - Basis for SNS JU Phase 1 Work Programme, Stream B, mainly B-01-01
  - SRIA 2022: updated and refreshed version of SRIA 2020
- Proposes a vision based on the actual evolution of ICT services
- Specifies a system architecture, as a real generalization of current models
  - Many (all?) current trends can be expressed as specializations
- Identifies technical areas required for a resilient operation on and of such a system



OVERVIEW

- **SRIA 2022 - System Architecture**
  - 45 pages, 7 sections, 15 Research Topics, **27 contributors**, 1 editor
  - Identifies 15 Research Topics, along with their descriptions, key outcomes (KPIs), contributions to the overall vision and/or society and required research actions

Research Theme	Virtualised Network Control for Increased Flexibility		
Research Challenges	Timeline	Key outcomes	Contributions/Value
Pervasive Resilient Autonomic Resource Control	Mid-term		Flexibility and universality Sustainability (in time) Trustw orthiness

⋮

Research Theme	Virtualised Network Control for Increased Flexibility	
Action	Pervasive Resource Control	Separation of Controllability and Control
International Calls		
International Research	X	
Open Data		
Large Trials		
Cross-domain research	X	X

- **Impact**
  - SNS Phase 2 Work Programme – direct impact on Strand B-01-01, System Architecture

TECHNICAL OVERVIEW

MAIN RECOGNIZED TRENDS

- **Nature of Communications: from servers to services**
  - Previously single-client to single-server to client to data centre with a PoP (big ICT, CDN, etc)
  - E.g. 61% of Asian Pacific Internet traffic actually served by CDN in 2021

  ➔ We estimate about 90% of traffic to be concentrated in customer access networks
- **Nature of Services: from monolithic to service chains**
  - Advances in microservices: easier to develop, maintain, analyze. Emergence of middleboxes.

  ➔ Single server replaced by chains of (collaborative) transactions, from DNS+IP to e.g. IETF SFC
- **Nature of Provisioning: virtualization, diversity**
  - Containers, unikernels replaces bare metal and increases deployment dynamics
  - Private / public, terrestrial / non-terrestrial, virtual / physical, remote / local, application / networking, compute / transport, etc.

  ➔ Services can be dynamically provisioned on load, concentration, under-performance, etc.

➔ **Integration of application and network, different service invocation model, different trust situation**

TOWARDS SMART GREEN SYSTEMS

- Problem for collaborative services: how to overcome traditional separation in silos?
- Future research must address **inter-computing**
- Opportunities:
  - Stronger and more capable devices in the network, at the edge and in the core
  - Proliferation of virtualization, providing portability and adjustable resource granularity
  - Densification of infrastructures, allowing to localize execution, loads, impacts, governance issues
  - New design, optimization and adaptation means, e.g., based on the advances of AI/ML
- Expected effects
  - Co-existence of physical and virtual entities, explicit involvement of different types of resources
  - Higher dynamics in both services and in the infrastructure

SYSTEM ARCHITECTURE VISION

Governance
through
- Customization
- Local compliance
- Security, isolation
- Correctness

of the service execution

Sustainability
through increase of
- Universality
- Cooperation
- Efficiency

at the resource level

→ **Mobile System ArchitectureS: per tenant needs!**

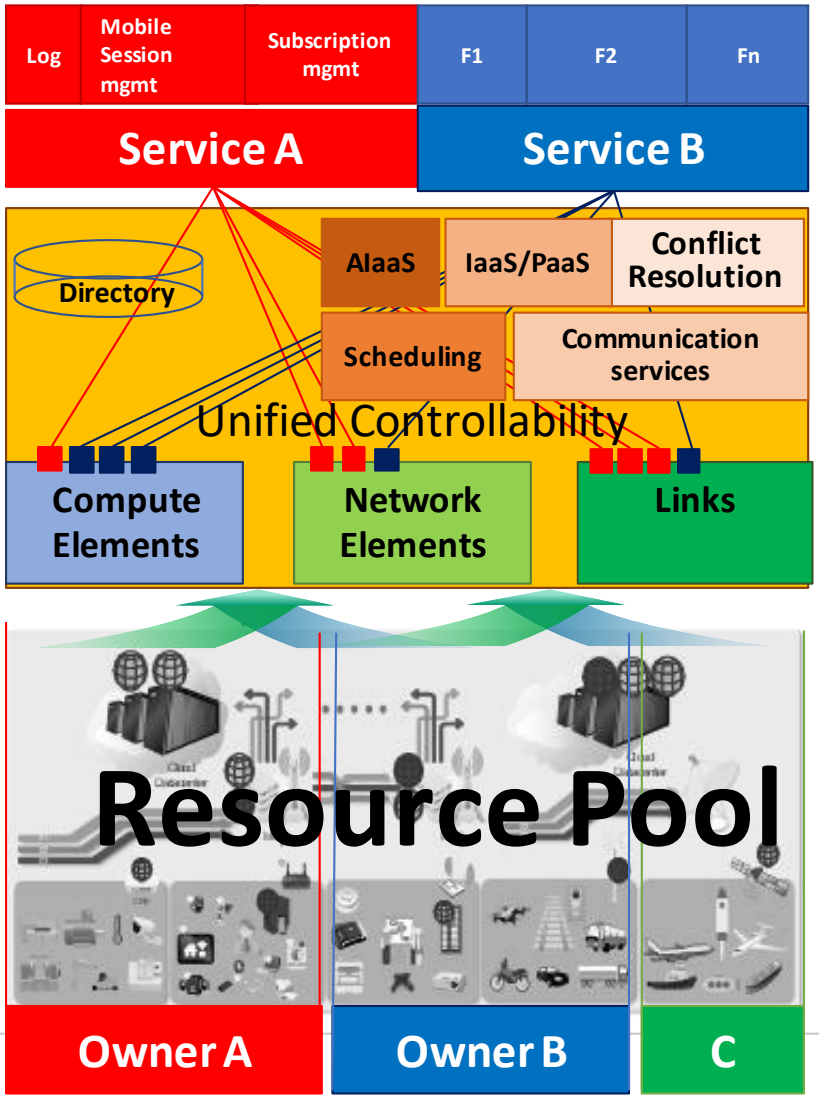
Accounts for the novel variety of the tenant types (NPN vs. MNO, compute integration, subscriber support for data governance)

- **Mobile system architecture**s allocated **as a service function chain**: preserves and upholds the flexibility of the modern infrastructures
- Emergence of new types of functions within the user, control and management planes to adapt to the capabilities of the infrastructure
- **Mobile systems** will look like **computer programs executed within the programmable infrastructure**

→ **Infrastructure: multi-tenant, composable, elastic**

- **Full-service platform (IaaS)**, commonly deployed and available to all
  - MNOs, NPNs, OTTs, subscribers, novel players
- **Native integration of all ICT resources, of any kind**
- **Native integration of AI/ML** as platform capability (particular PaaS), usable both for the system itself and for the executed services over APIs
- **Native and natural integration of terminals** just as of any other resource

6G as a Smart Service Execution Platform

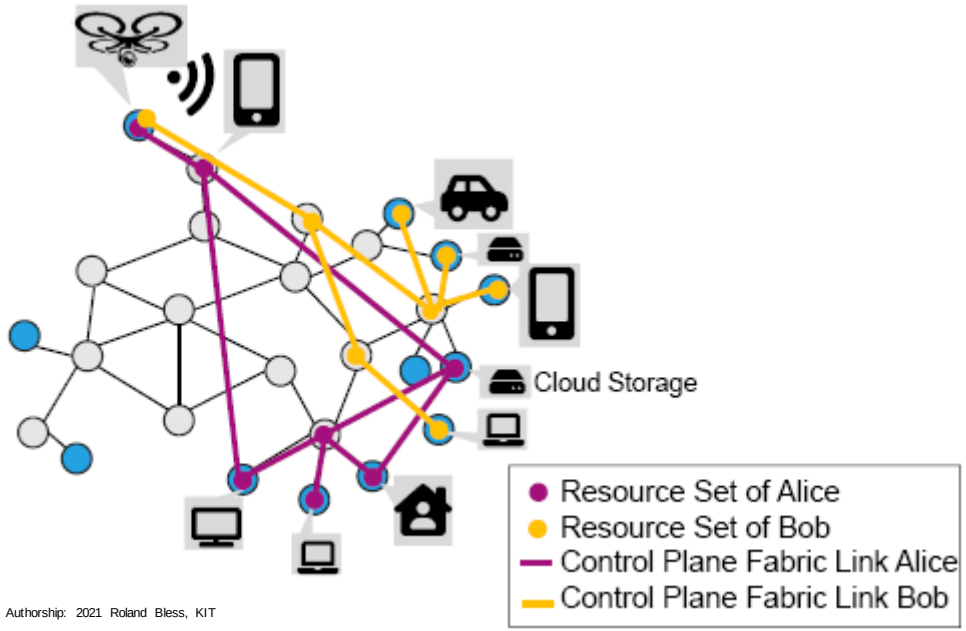


HOW CAN THIS WORK? REQUIREMENTS

- Resource continuum: need to support a dynamic pooling of various types of resources from diverse participating tenants, systems, devices and objects.
- Flexibility in services, with recursion: enable seamless allocation of complex IT objects over selected (groups of) IT objects and controllable resources
  - IT objects: ranging from atomic modules to compound services. Allow object reuse (APIs, control)
  - Controllable resources: depending on the controlling entity, this is what ends the recursion
- Self-sustainability: need to integrate autonomics to enable both self-organized, resilient programmability and elastic, correct execution of any IT objects.
- AI/ML integration: as IT objects of particular interest, AI/ML objects offer programmable analytics and cooperative machine learning to the respective service layer through open interfaces.

PERVASIVE RESOURCE CONTROL

- Problem
  - Assuming a changing resource pool, how can a tenant control the assets?
  - What if somebody else's management decisions look like sudden failures?
  - What if your own decisions can disconnect some assets?
- Needed:
  - Scalable, Flexible, Zero-touch routing protocol
  - Suitable for virtualized and highly dynamic environments

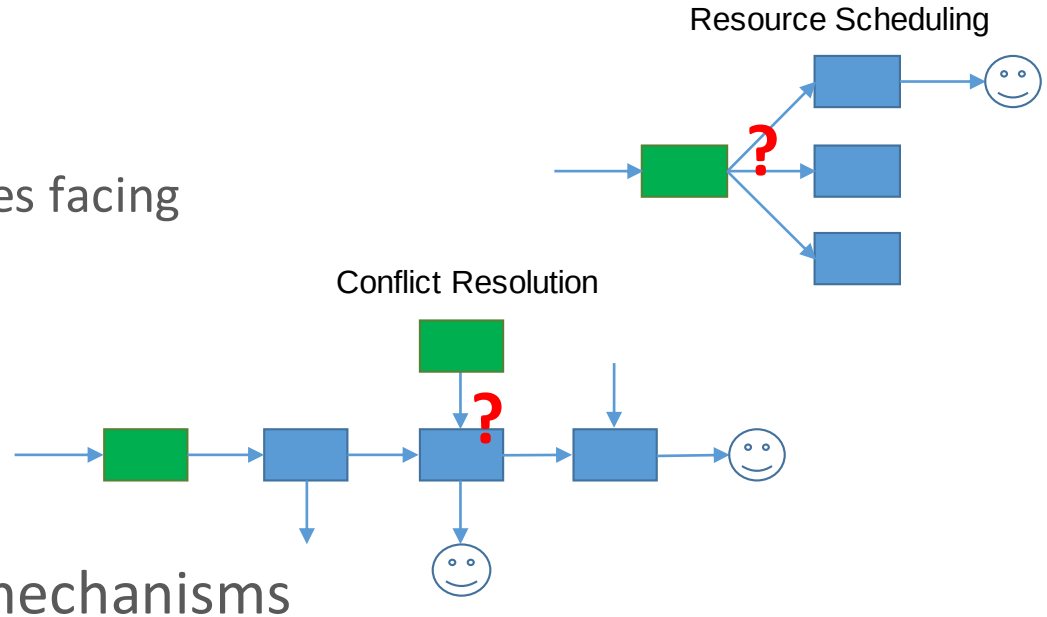


TOWARDS COMPUTE INTER-CONNECTION

- Problem
  - Service understanding and invocation both radically changed from "$A^x \rightarrow B$" to "A: f(x)"
  - Requires collaborative computing by some capable entities/objects
    - How to break f(x) into blocks? How to find realizations for blocks? How to assign them in runtime?
  - Chicken-Egg: even if many things can be allocated or programmed – what is the common basis?
    - Which layers? Which addressing? What is allocated where?
- Needed: support for highly performant inter-computing
  - Novel user plane protocols with novel semantics, supporting user-to-system interaction
  - Some sort of semantic addressing
  - Runtime selection of resources for identified tasks (not necessarily optimal)

EFFICIENCY AND RESOURCE MANAGEMENT

- Problem
  - How to guarantee / uphold extra-functional properties facing
    - Dynamics
    - Multi-tenancy
    - Large scale
- Needed: integrated efficiency and correctness mechanisms
  - Distributed Runtime Service Scheduling
  - Distributed Conflict Handling means (avoidance / resolution)
  - Networked Garbage Collection



NATIVE INTEGRATED AI/ML

- Problem
  - How to bootstrap AI/ML instrumentation along with the network?
    - Transform "network" to a multi-user, cooperatively set up, distributed AI/ML system
- Needed
  - Truly distributed AI/ML instrumentations (beyond federated learning)
  - Reliable AIaaS support, including on transient / limited resources
  - Resource-aware or Net-zero AI/ML (including auto-awareness)
  - AI/ML driven system updates, system self-evolution

DEEP EDGE, TERMINAL AND IOT INTEGRATION

- Problem
  - How to integrate deep edge resources?
  - How to integrate terminals into the system and service provisioning?
  - How to integrate potentially weak terminals, like IoT devices?
  - How to feed back new capabilities in e.g. sensing, autonomics, etc. to devices?
    - Device augmentation
- Needed
  - Integration of IoT architectures as typically considered service, with special constraints
  - User centric dynamic virtualization support (include terminals into virtualization platform)
  - Edge intelligence

CHANGELOG: SRIA2020 TO SRIA2022

- General: refresh with precisions on
  - Architecture (layers, modules, required services / support at different layers)
  - KPIs, value and purposes of all technologies
  - Energy consumption / Carbon footprints of the future compute-integrating networks
- AI/ML: underlined the importance of
  - Distributed AI/ML, now stressing the potential for learning on constrained devices
  - Resource-aware AI, i.e., AI that considers its own costs
  - Self-programmability: precisions on creation of NFs and SFs by the integrated AI
- User plane now more explicitly integrates compute capabilities
  - Transport as a multi-point Compute-Inter-Connection facility
- Terminal / Deepest Edge integration
  - Specific architectural needs for e.g. IoT
  - Reliable service execution on transient resources, i.e. confined to the edge/terminals
  - Edge AI considerations, with inference support on the terminals directly

CONCLUSION

- Proposed System Architecture
  - Is a real generalization of existing architectures
  - Explicitly tries to support radically different services on different resource pools, as per tenants
  - Breaks down this to a set of required research advances
- The architecture explicitly addresses sustainability
  - In time: through performant new protocols/architectures/addressing for CIC and flexible service definition, evolvable design, including in its own functions
  - In governance: through support of specifically crafted, e.g. specifically localized executions, as per tenant & service & user requirements
  - In energy: through support for (autonomic) resource overhead limitations and (intelligent) dynamic assignment

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THANK YOU FOR YOUR ATTENTION

And special thanks to all contributors!

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