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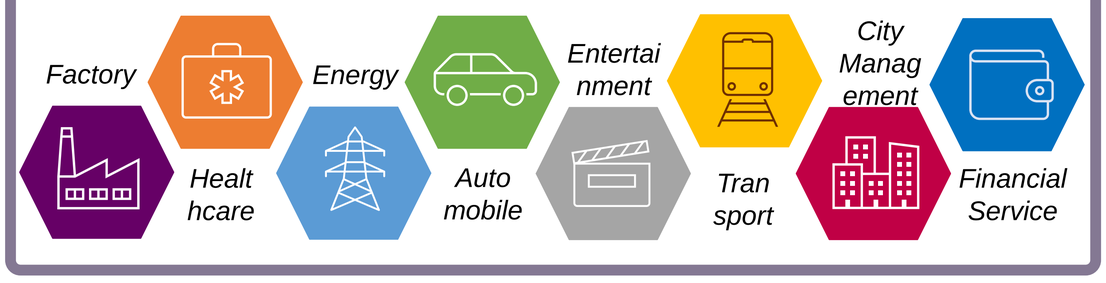
Modeling of a 5G (or Beyond 5G) network to estimate its capacity to meet the resilience requirements of verticals

Introduction

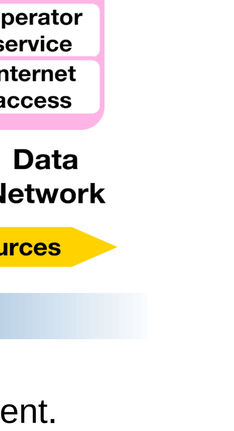
- The 5G promise of a complete networked society with unlimited access to information about anything for anyone demands key features beyond what the current 4G offers [1].
- 5G redefines service delivery model and it becomes more vertical industry-oriented[2].
- 5G or beyond networks should be able to deliver services that satisfy the requirements, especially resilience requirement of all kind of service.



Objectives

- Define resilience for 5G system.
- Understand the specific requirements and resilience requirements of different verticals (e.g., smart grid) and translate them into criteria.
- Develop a model to estimate or measure the 5G network resilience performance.

Current work
- Understand 5G architecture
- Delimit research scope and choose use cases
- Build a model to simulate network service delivery

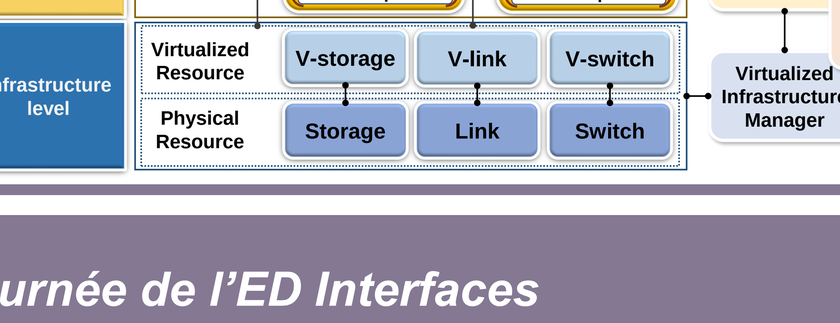


Expected work
- Verify if service requirements are met
- Generalize the model to simulate all use cases
- Optimize facilities installation and network configuration

5G System Architecture

End-to-End perspective

1. Integration of a network service.
2. Placement flexibility of Network functions blur network boundary.



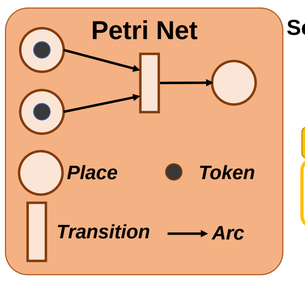
Multilayer perspective

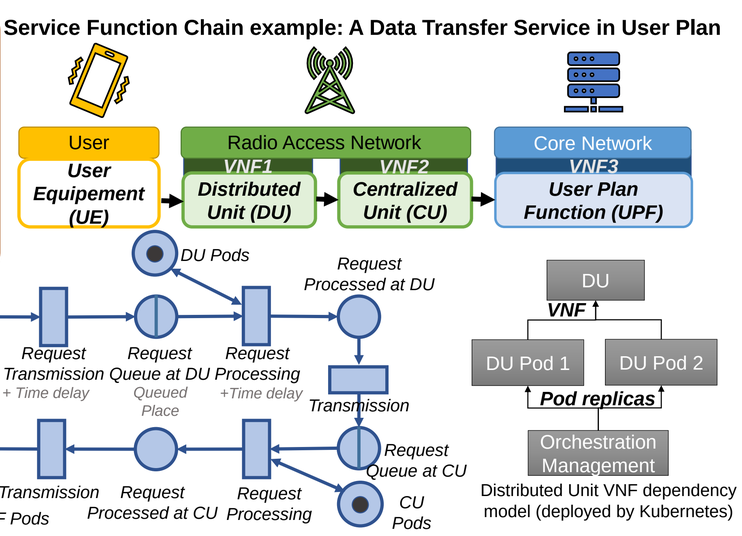
1. NFV and SDN Improves network performance.
2. New challenges in orchestration and management.

Modeling

- 5G network Model
  - 5G end-to-end service processing
    - Service function chain
    - Mapping virtual layer with physical layer
  - Failure injection
    - Simulating failure and failure propagation in different layers of 5G system
  - Orchestration and management
    - Self-healing process[3]: gracefully terminate failed elements and create new ones
    - Auto-scaling process[4]: adapt the network deployment according to traffic
- Metrics:
  - Service latency, Service reliability, etc.

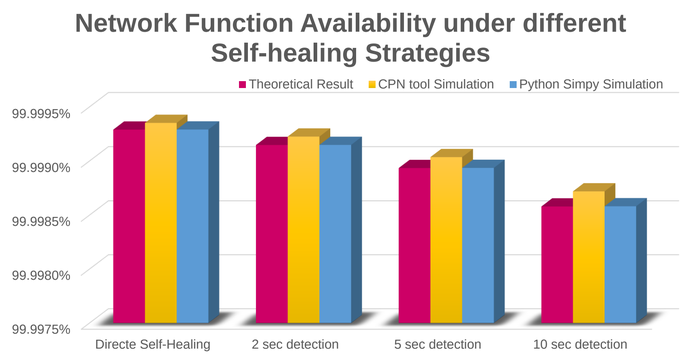
- Petri Nets and their concepts have been extended, developed and applied in various areas: work-flows, performance evaluation, embedded systems, protocols, telecommunications.
- We use a Timed Stochastic Colored Petri Net to describe the 5G system.





Simulation Results

- Self-healing process with different strategies



- A container-based management and orchestration unit regularly detects the healthiness of network functions and their components. In case of failure, they will be terminated, and new ones will be created.
- We define the availability of network function i as:

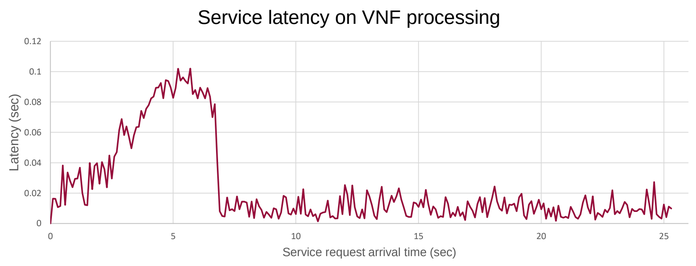
$$A_i = \frac{\text{Network Function } i \text{ uptime}}{\text{Total Simulation time}}$$

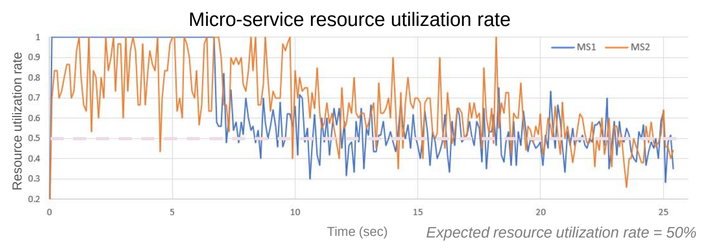
A network function is up only when the component's replicas are greater than the desired number.

- We compare theoretical results based on the Reliability bloc diagram with simulation results based on the model in CPN tools. The comparison shows a good prospect to use Petri Net to describe 5G network. Due to the constraints in CPN tools, we use Simpy framework to complete the model whose result is much closer to the theoretical result.

- Auto-scaling process based on resource utilization strategy

- The management and orchestration unit may also change the network functions and their components' scale according to the packet traffic. One common way is to detect resource utilization. A desired resource usage rate is set as a reference. When the resource utilization is higher than the upper limit, then a scaling out process will be scheduled, vice versa.
- We simulate the process of a network service inside one VNF with two kinds of components (micro-services). When the traffic is too much for the VNF to handle, the resource utilization rate will be high, and service latency will increase due to the lack of resources. Auto-scaling takes action quickly when this happens, and new component replicas are added to this VNF which gradually reduces the service latency and resource utilization rate.





Future Work

- A case study on multiple management in case of network failure will be carried out on the next stage to estimate 5G network resilience better.
- More service level requirements will be considered to evaluate the quality of service.
- We also intend to expand the case study from one single VNF to an SFC and apply the model to simulate a real 5G and beyond use case from the verticals.

References

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[3] J. Ali-Tolppa, S. Kocsis, B. Schultz, et al., Self-healing and resilience in future 5G cognitive autonomous networks, *2018 ITU Kaleidoscope: Machine Learning for a 5G Future (ITU K)*, 2018, pp. 1-8.
[4] S. Rahman, T. Ahmed, M. Huynh, et al., Auto-scaling VNFs using machine learning to improve QoS and reduce cost, *2018 IEEE International Conference on Communications (ICC)*, 2018, pp. 1-6.

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