Coordination Models for 5G Multi-Provider Service Orchestration:

Specification and Assessment

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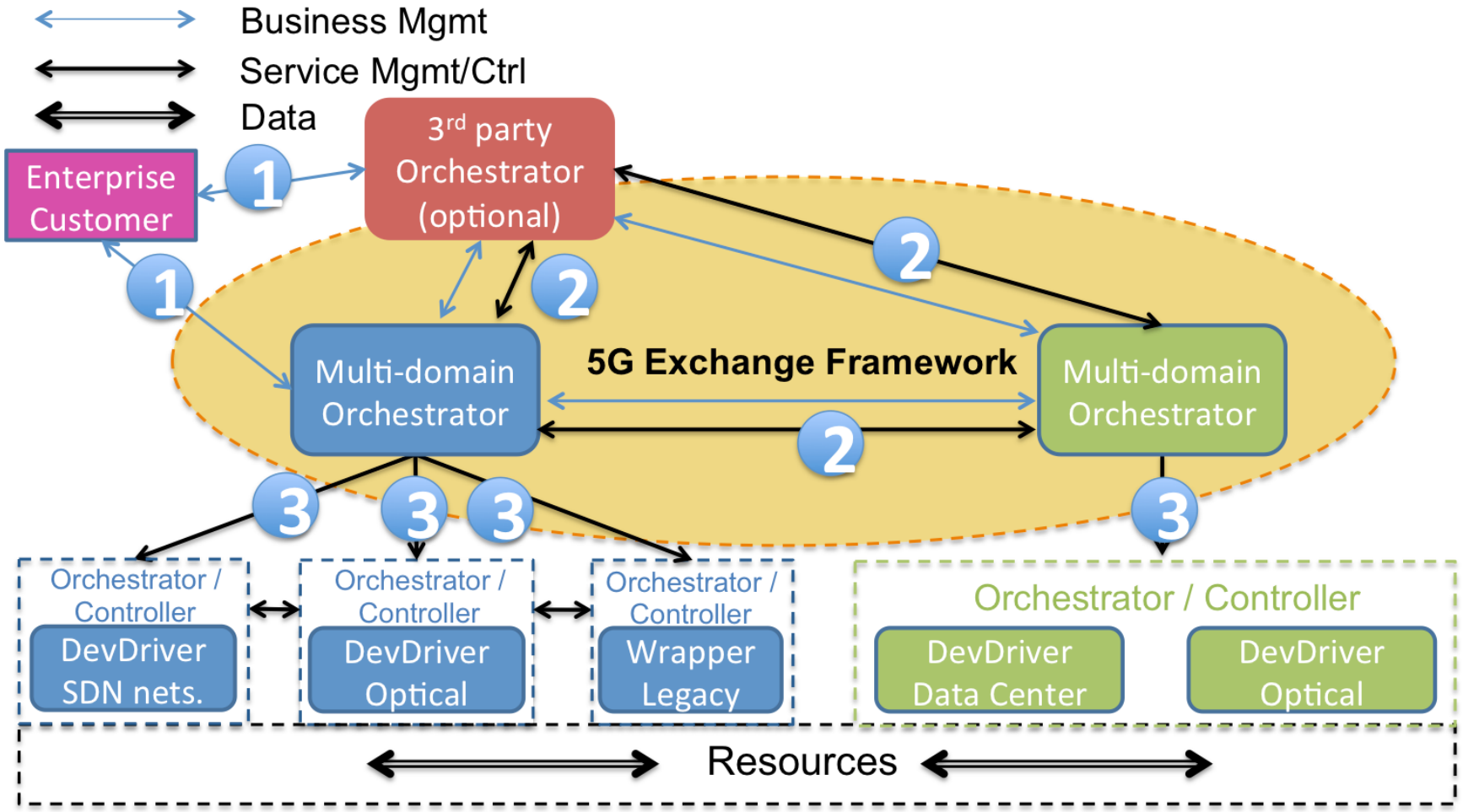
Introduction

- 5G is an all-IP **fully softwarized network architecture** from core to the edge
  - Exploits the emerging virtualization technologies in all compute, storage and network domains.
    - ✓ *NFV, SDN, Cloud computing, …*
  - Softwarization allows the fast-agile trade, deployment, orchestration and management of 5G multi-provider services.
    - ✓ *Support verticals of **unprecedented end-user QoS requirements** over the domains of Infotainment, e-Health, Energy, Auto-motive, etc.*
- The 5G verticals/customer facing services rely on **wholesale infrastructure services**
  - Assured Service Quality (ASQ) Connectivity
  - Network Function Virtualization Infrastructure as a Service (NFVIaaS)
  - Slice as a Service (SlaaS)

Motivation

- The **value chain of 5G** inherently involves multiple stakeholders of todays Internet.
  - Network Service Providers (NSPs)
  - Infrastructure Service Providers (IfSPs)
  - Over-the-top Providers
  - ….
- Multi-actor service chain complicates the task of **end-to-end service composition** and **inter-provider coordination.**
- **Need** for business and service coordination models
  - Adoption of sophisticated **service Orchestrators** is vital.
    - ✓ The exchange of information between Orchestrators has great impact on the **efficiency of the 5G service composition**.

5G Exchange Orchestration Framework

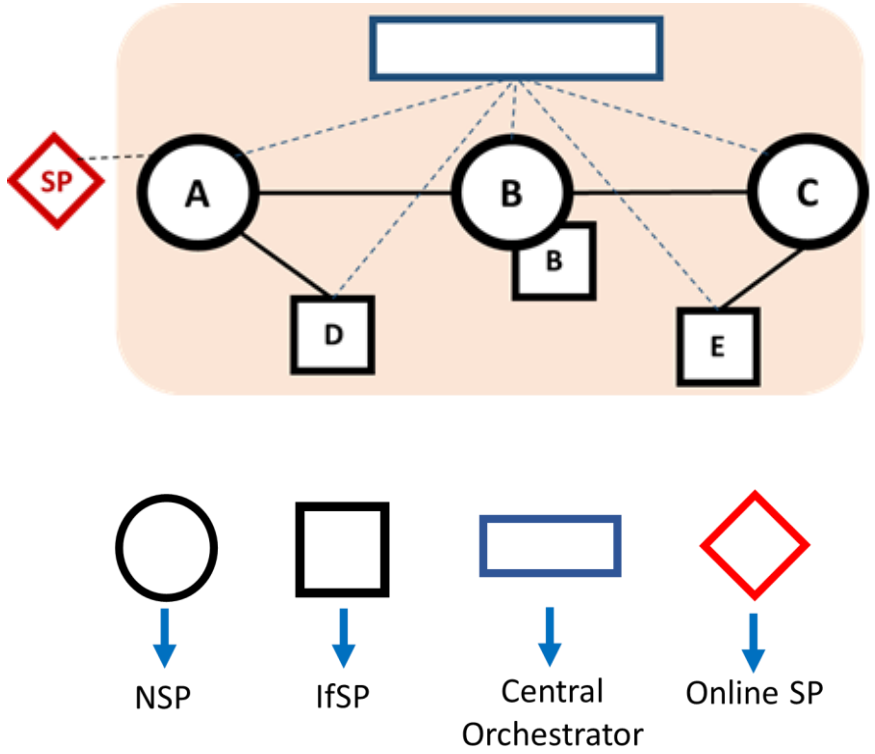


Coordination Models

Coordination Model Characteristics

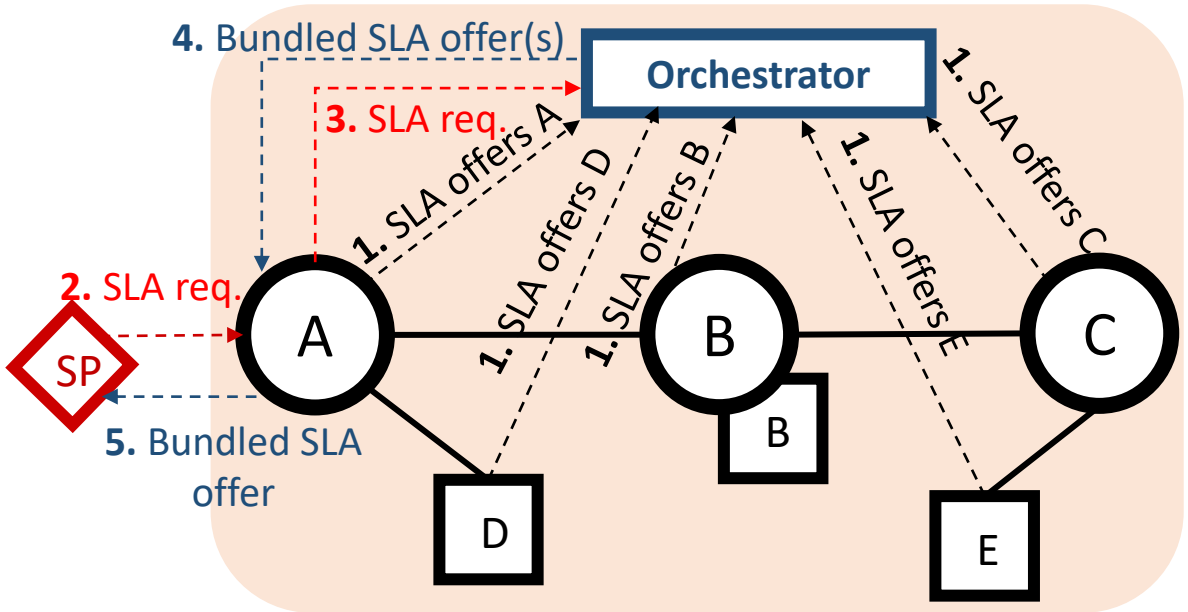
- **Distributed** vs **Centralized**
  - Distributed coordination through **bilateral** communications, **or** centralized through a central **Orchestrator** for information/service aggregation.
- **Fully Centralized** vs **per-Provider Centralized**
  - In the per-Provider centralized model, **multiple central Orchestrators** co-exist, each serving a different cluster of providers.
- **Coordination model phases**
  - **Publishing phase** specifies the extent of the information exchanged regarding the service offerings.
  - In the **service composition** the providers use the information gathered during in their publishing phase to compose services.
- **Push** vs **Pull**
  - **Push:** the providers ***publish*** **SLA offers.**
  - **Pull:** the providers ***publish*** **service capabilities**

5G Ecosystem



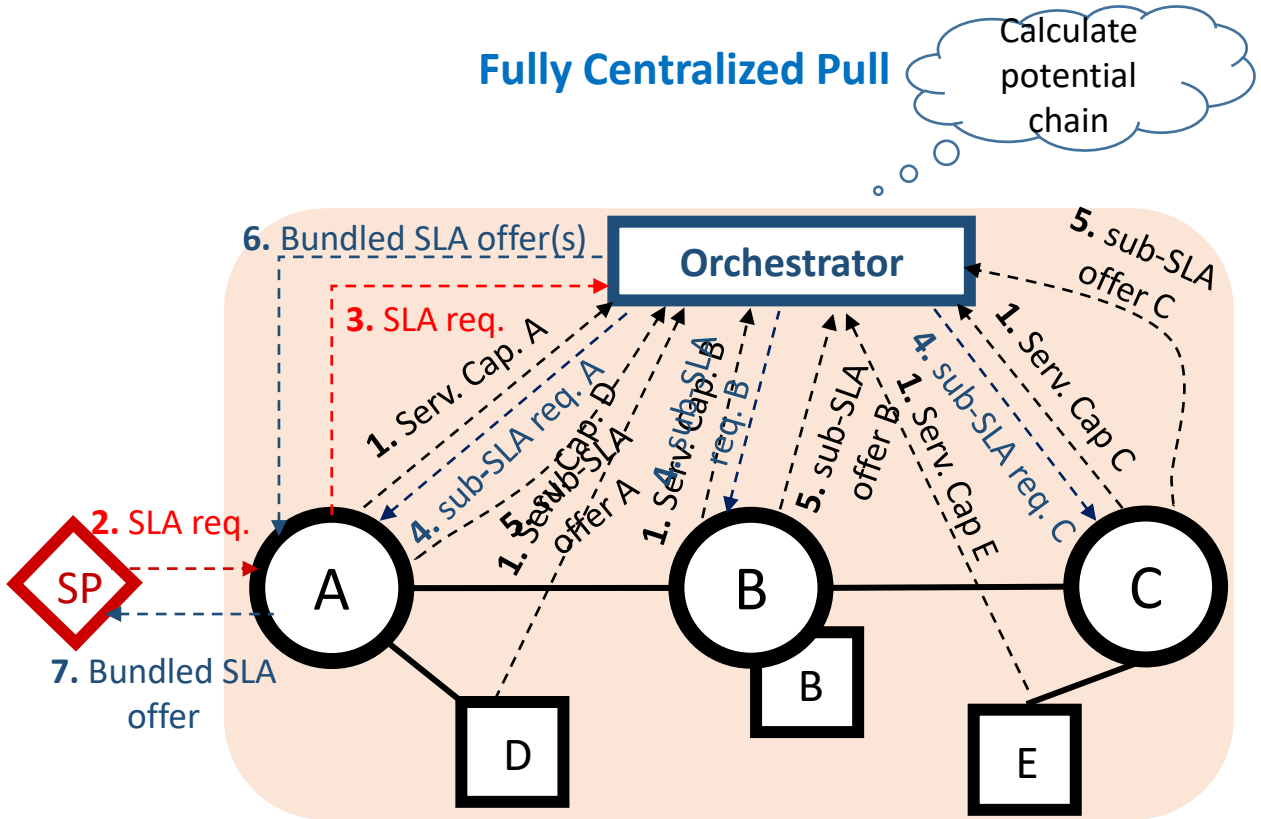
Fully Centralized Coordination Models

Fully Centralized Push



Publishing Phase **Composition Phase**

Fully Centralized Pull



Publishing Phase **Composition Phase**

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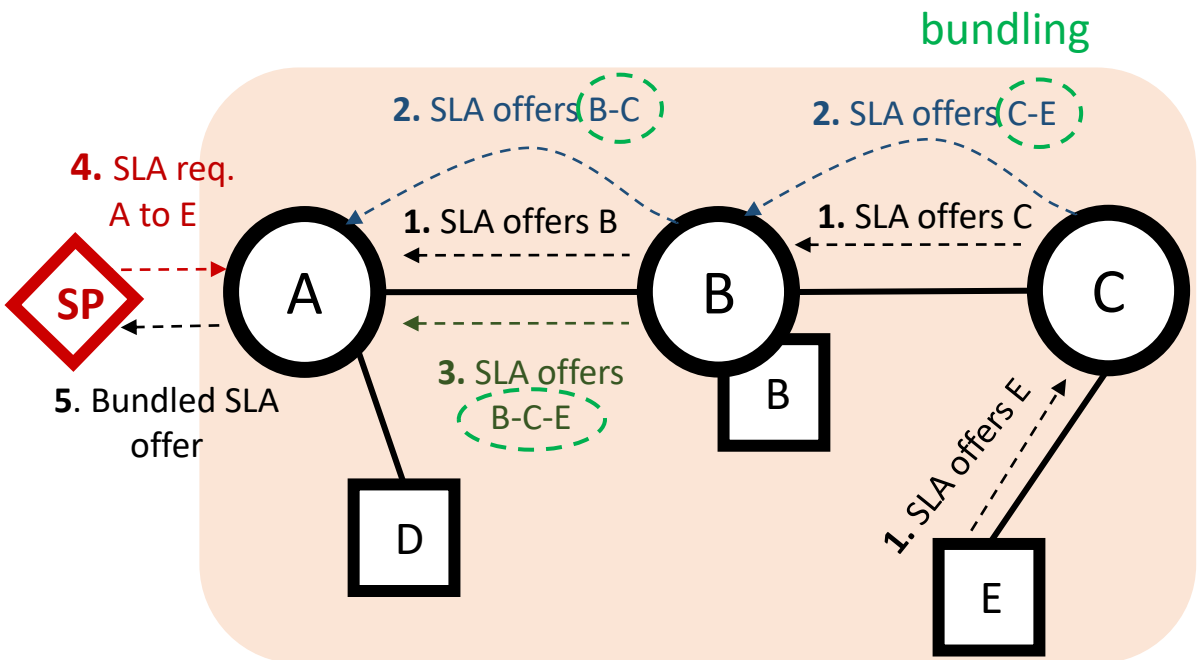
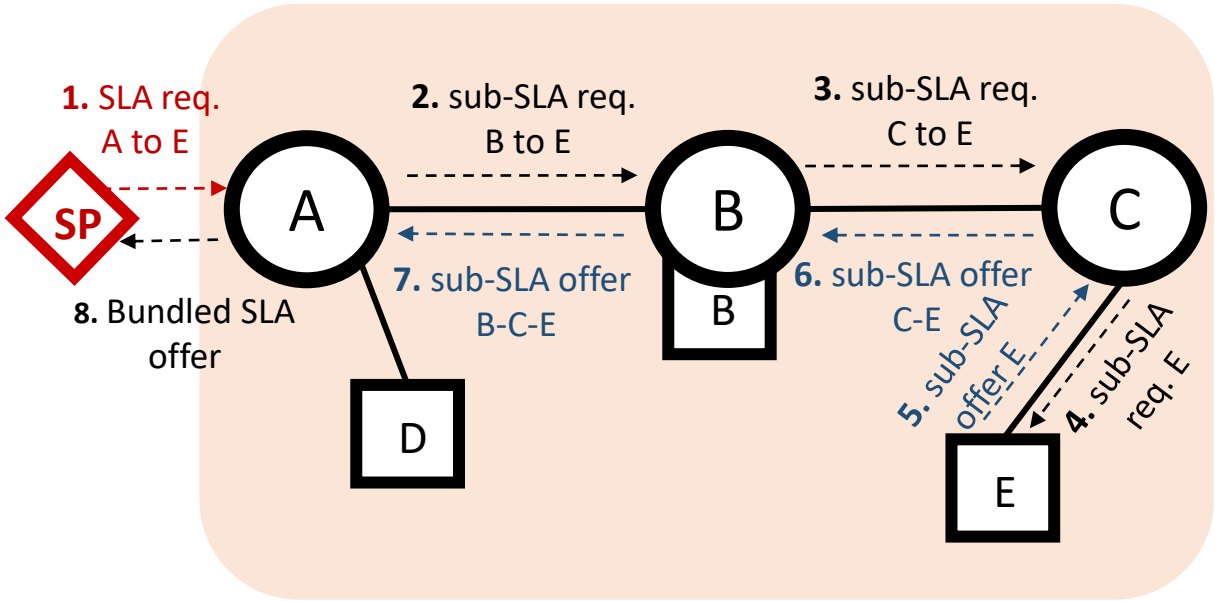
Distributed Coordination Models

Distributed Push



Publishing Phase **Composition Phase**

Distributed Pull



Publishing Phase **Composition Phase**

Same process as in the push model but for **service capability** announcements instead of SLA offers

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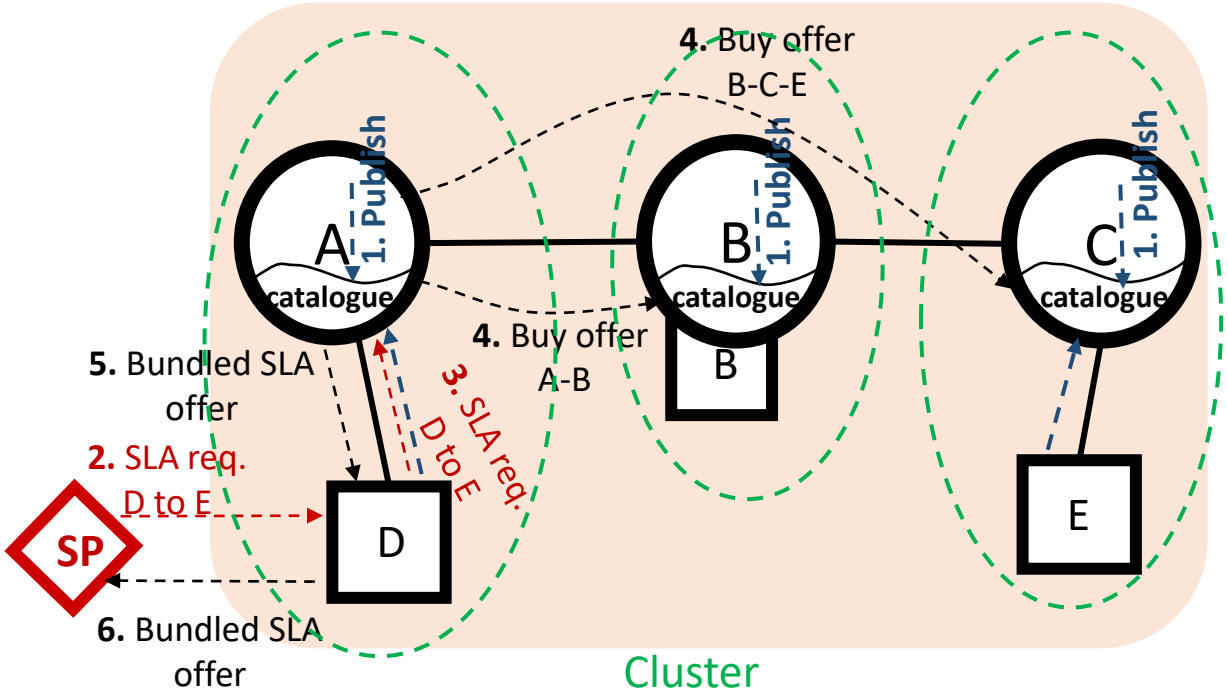
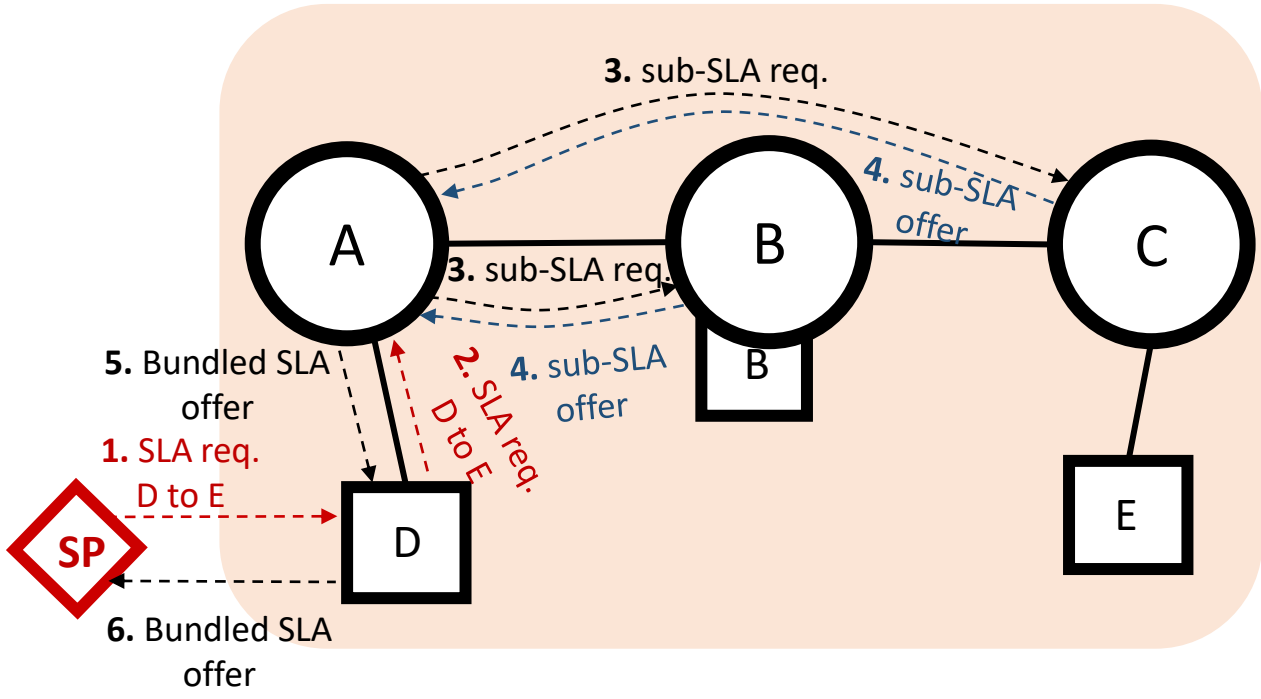
Per-Provider Centralized Models

per-Provider Centralized Push



Publishing Phase **Composition Phase**

per-Provider Centralized Pull



Publishing Phase **Composition Phase**

Same process as in the pull model but for **service capability** announcements instead of SLA offers

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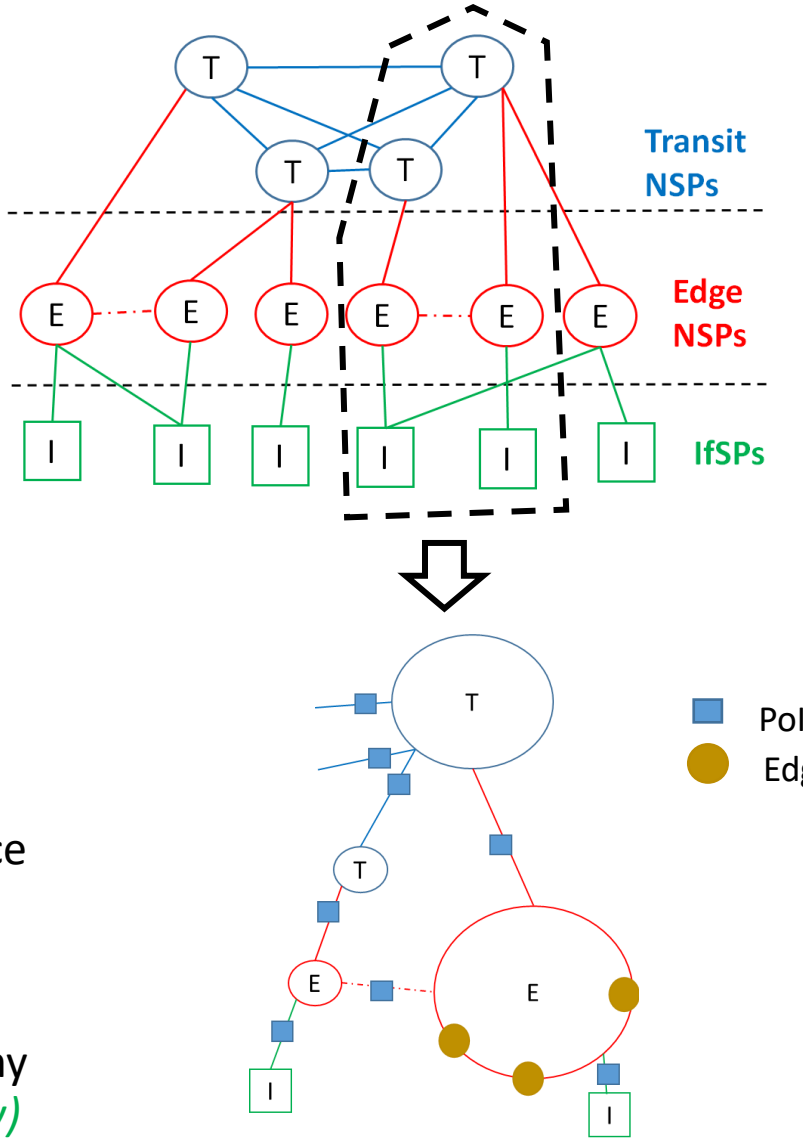
Assessment Methodology

- **Service domains**
  - ***Transit NSPs*:** offer services only in **N** domain
  - *Edge NSPs*: offer services in all N, C, S domains
  - ***IfSP*:** offer services in **C and S** domains
- **Service characteristics**
  - Multiple **service types** per service domain
    - ✓ **Multiple** *SLA offers per service type (1 per-QoS level)*
    - ✓ *A **single** service capability announcement per PoI-to-PoI/PoP pair.*
- **Service requests** arrive only to Edge NSPs and IfSPs.
  - Generation of **random requests** w.r.t source, destination, service domain, QoS level, etc.
- **Intense bundling** *(for Distributed models)*
  - There are bundled SLA offer or service capabilities to reach any destination within the orchestration framework. *(100% availability)*



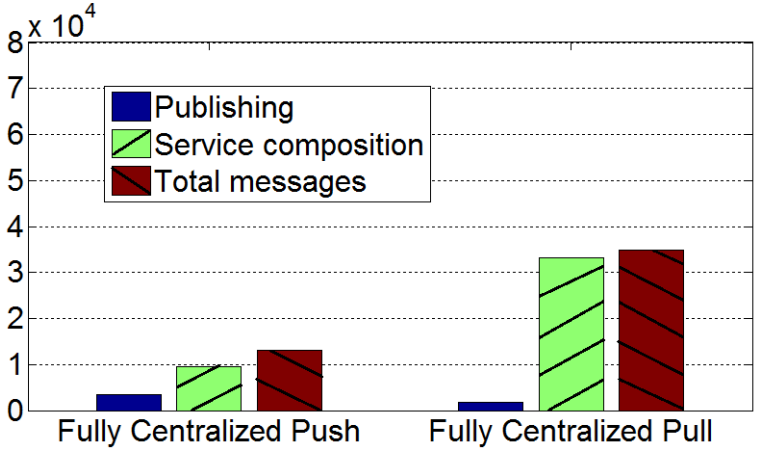
Assessment Methodology (II)

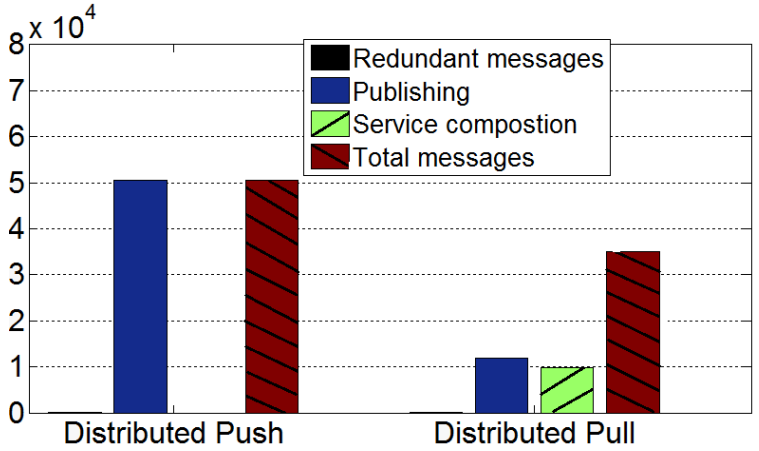
- **Baseline simulation setup**
  - T-NSP=5, E-NSP=20, IfSP=40
  - 1 **PoI** per neighbor, 5 **PoPs** per E-NSP
  - 2 **SLA offers** (and levels of QoS) per service type, 1 **service capability** per PoI pair,
  - 30 **service requests** per E-NSP and IfSP.
  - **Intense bundling:** Providers can reach any destination within the 5G orchestration framework.

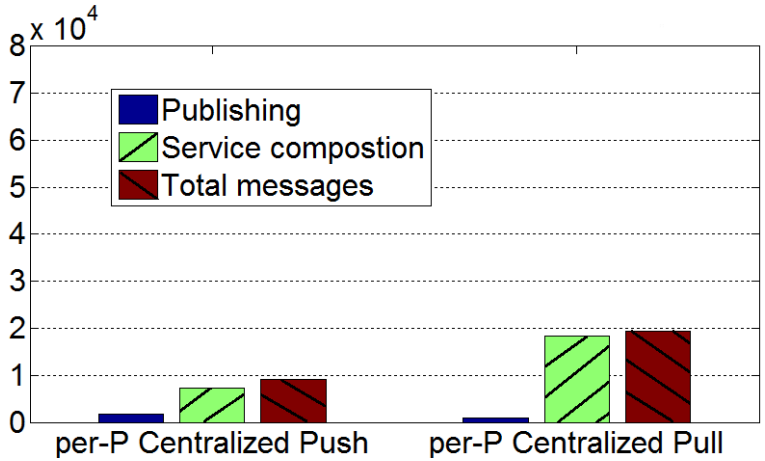
- **Sensitivity analysis parameters**
  - # of T-NSP, E-NSP and IfSP
  - # of QoS levels
  - # of PoPs per E-NSP
  - # of request per E-NSP and IfSP.
  - Bundling intensity
- **Metrics**
  - **Message overhead** (scalability)
  - **SLA offers / service capabilities availability** (service composition efficiency)

Sensitivity Analysis Results

- **Message overhead for all models under baseline setup**
  - Highest in the Distributed models / lowest in the per-Provider Centralized ones.
  - **Pull models** generate fewer messages than push during the ***publishing phase***
    - ✓ *service capabilities are more compacted to SLA offers.*
  - **Push models** require the exchange of fewer messages for the ***composition*** of each service.







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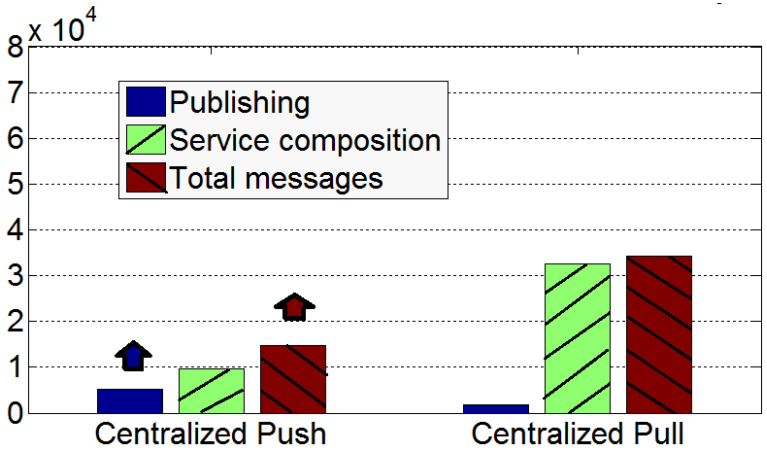
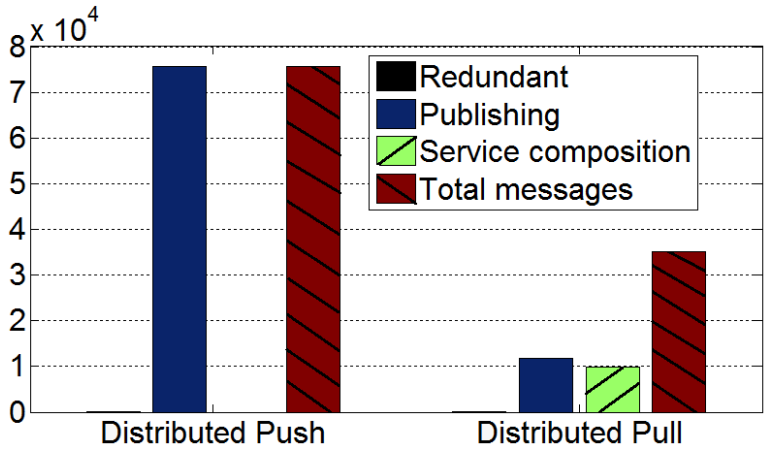
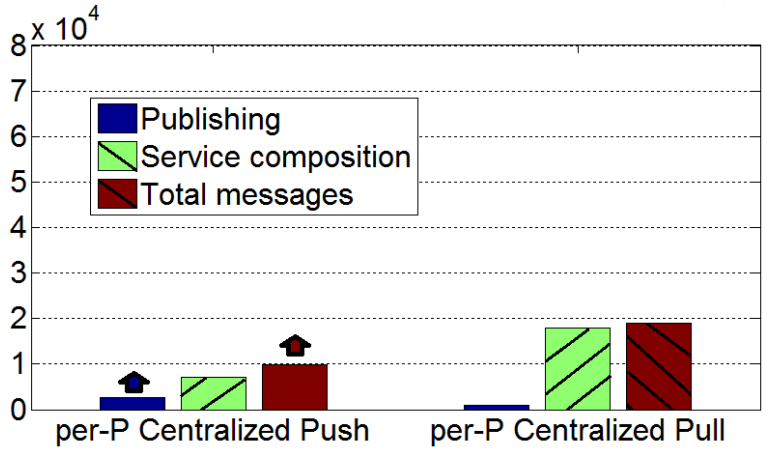
Sensitivity Analysis Results (II)

- **Impact of the number of available QoS levels** (2 vs 3 QoS levels)
  - **Pull models** are not affected since 1 service capability announcement that covers all QoS levels will be pushed.
  - **Push models** are affected since a different SLA offer will be pushed for each QoS level.
    - ✓ ***Distributed push*** *is the most* ***"sensitive"*** *due to the intense bundling.*
    - ✓ *The* ***Fully and per-Provider Centralized push*** *models are also affected, but they are* ***less sensitive****.*







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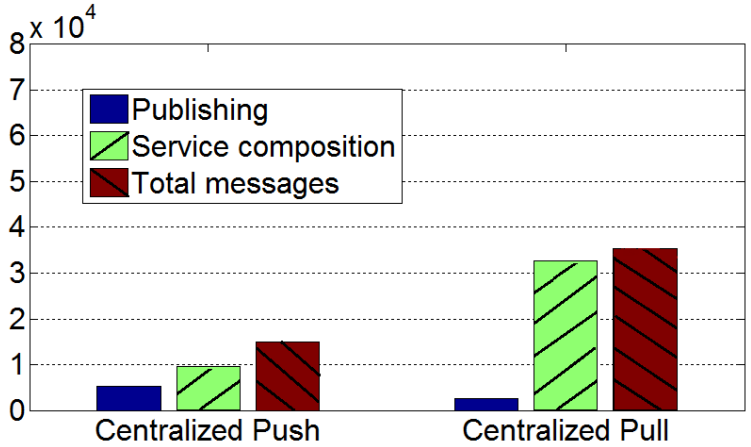
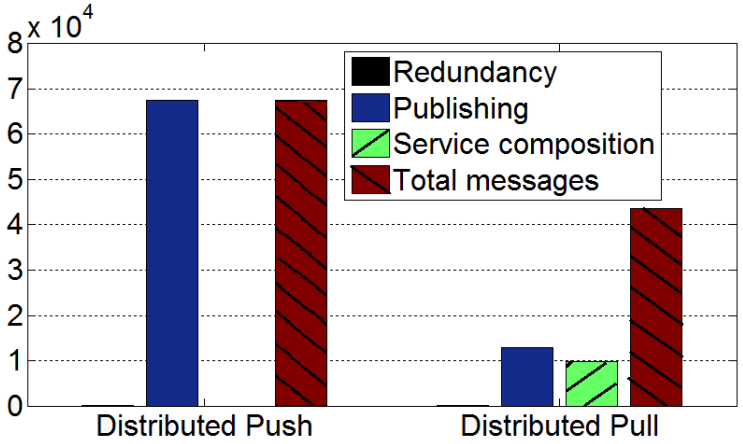
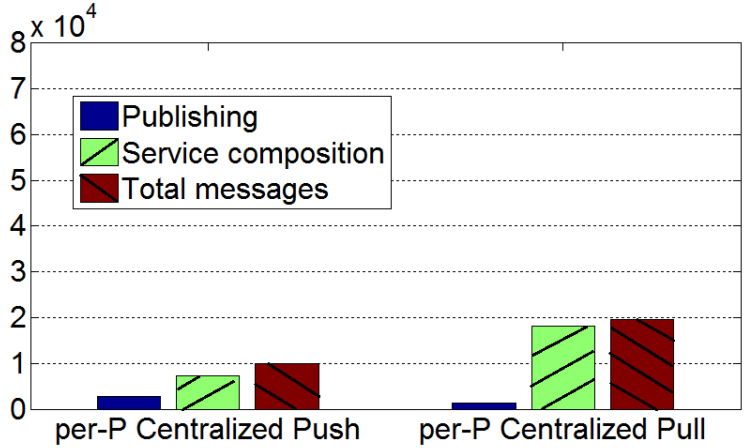
Sensitivity Analysis Results (III)

- **Impact of the number of Edge PoPs** (5 vs 10 Edge PoPs)
  - **Distributed models** are affected more than the Centralized ones where the impact is minor.
    - ✓ *The **increased number of destinations** within the orchestration framework greatly increase the **impact of bundling**.*
  - The number of Edge PoPs affects the message overhead of **push and pull** models in the **same extent**.







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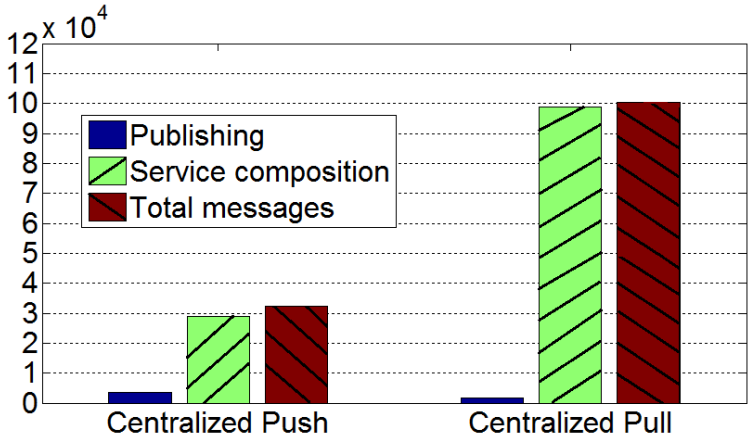
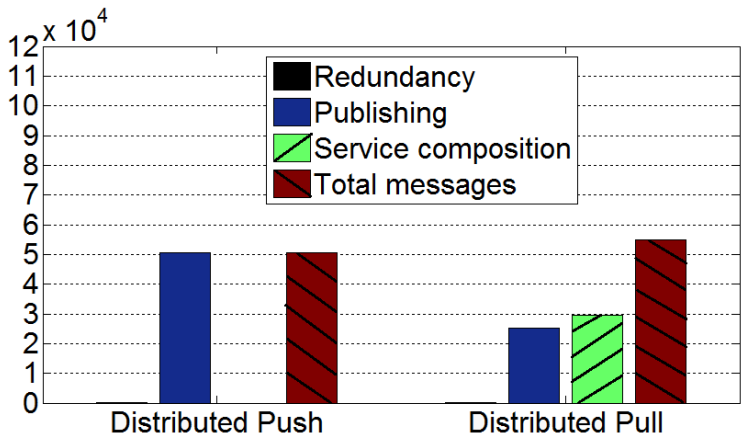
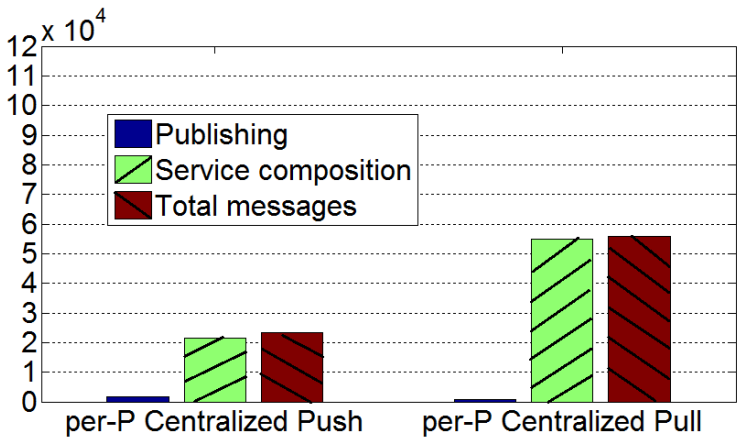
Sensitivity Analysis Results (IV)

- **Impact of the number of service requests** (30 vs 90 requests per E-NSP/IfSP)
  - The number of requests affects the **service composition phase** of each model
    - ✓ *The **Centralized Pull** affected the most since the Orchestrator must exchange increased number of messages with E-NSPs and IfSPs being at the edge of the network.*
    - ✓ *The **per-Provider Centralized pull** is affected less, since the multiple Orchestrators are closer to the edge providers of their cluster.*







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Sensitivity Analysis Results (V)

- **Impact of the number of T-NSPs, E-NSPs and IfSPs**
  - An increase on the **number of IfSPs** significantly increase the message exchange of all models
    - ✓ ***85%*** *increase in Fully Centralized,* ***180%*** *in Distributed,* ***83%*** *in per-Provider Centralized models.*
  - An increase on the **number of E-NSPs** the message overhead is **increased** by
    - ✓ ***27%*** *in Fully Centralized,* ***75%*** *in Distributed and* ***16%*** *in per-Provider Centralized models.*
  - **By doubling** the total number of providers, the message overhead is **doubled** in Fully and per-Provider Centralized models, but the increase is **exponential** in the Distributed ones.

Transit NSPs	Edge NSPs	IfSPs	Total Number of messages					
-	-	-	C-Push	C-Pull	D-Push	D-Pull	P-Push	P-Pull
5	20	40	13022	34813	50476	35016	**9026**	19288
10	20	40	13286	34781	54720	37026	**9226**	19354
5	40	40	16414	43225	87421	57301	**10887**	23268
5	20	80	23952	59914	138680	85496	**16673**	33544
10	40	80	26932	70720	207846	123536	**18651**	39120

Sensitivity Analysis Results (VI)

- **Bundling intensity and SLA offers availability**
  - Under **intense bundling**, Distributed models do not scale.
  - A restriction on the **maximum hops** a bundled SLA offer can reach may mitigate this issue.
    - ✓ *restrictions may lead to low availability of SLA offers, hence customer requests for remote PoPs cannot be **immediately** satisfied.*
  - The **results** show
    - ✓ *A bundling policy of **maximum two SLA offers** (3 hops), the message overhead is lower than all the other coordination models but the SLA offers availability drops to 19%.*
    - ✓ *A bundling policy of **maximum three SLA offers** (4 hops) leads to an availability of 56% but for double the message overhead of the Centralized models.*
    - ✓ *Note that after **bundling four SLA offers** all destinations in our topology can be reached.*

Conclusions and Future Work

- We introduced multiple **coordination models** for the service composition in the 5G multi-provider ecosystem.
- We simulated an **Internet-like environment** of multiple 5G providers and evaluated the models under different setups
  - **Sensitivity analysis** on the different parameters of the ecosystem.
- Our results reveal that
  - **Distributed** models scale significantly worse than Fully and per-Provider Centralized models.
  - As the ecosystem becomes larger the **hybrid/per-Provider Centralized models** scale best.
- **Future work**
  - Evaluation of the coordination models over **different topology structures**.
  - Define **smart bundling policies** for the Distributed models.
  - Investigate how the **pricing policies** are affected by the selected coordination models.

Thank you for your attention!

Questions?

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