Hyperconnected Urban Logistic Service Networks: Bidding-Based Design Framework

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Joint work with

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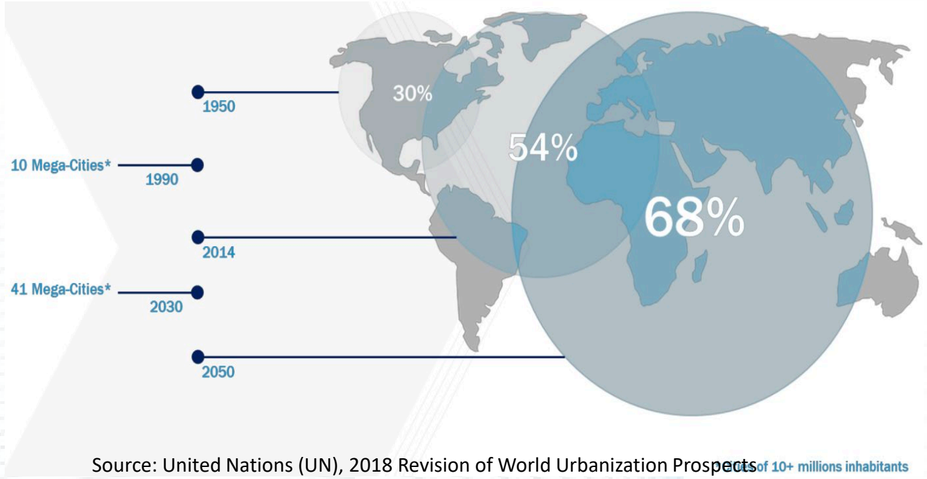
alice Alliance for Logistics Innovation through Collaboration in Europe

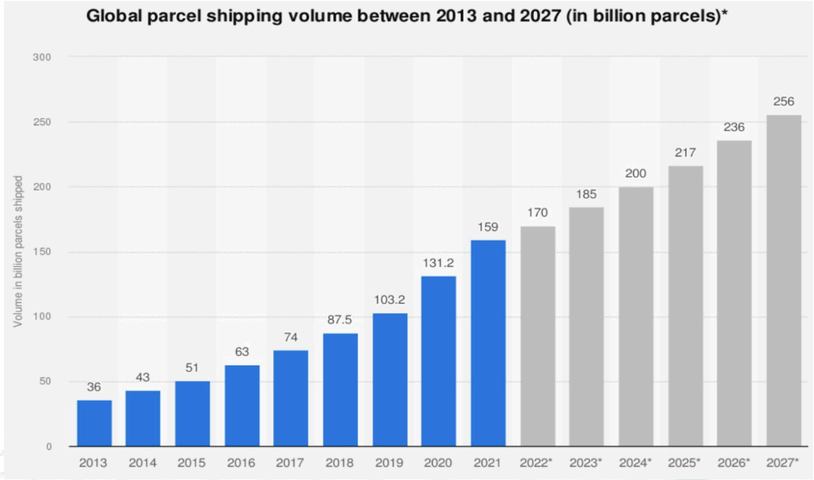
Expanding the logistics Scope

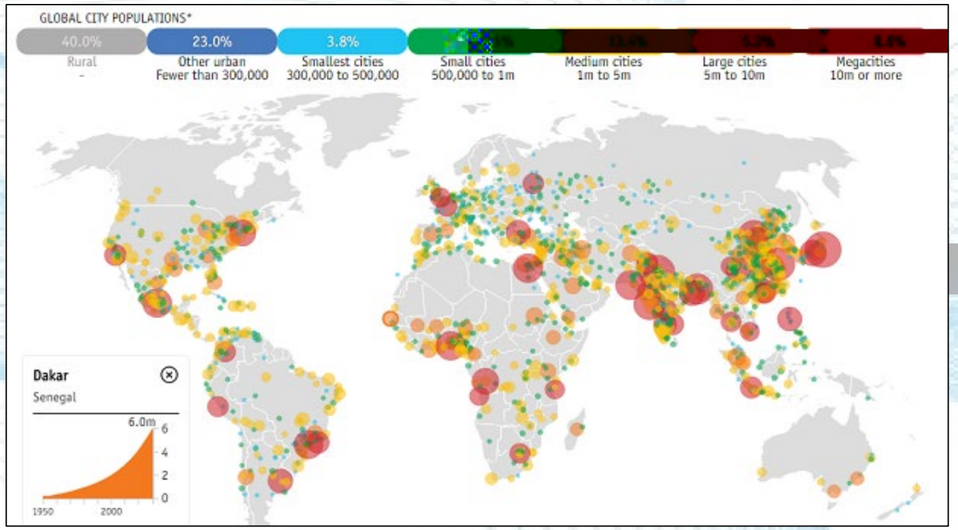
Motivation: Challenges in urban cities

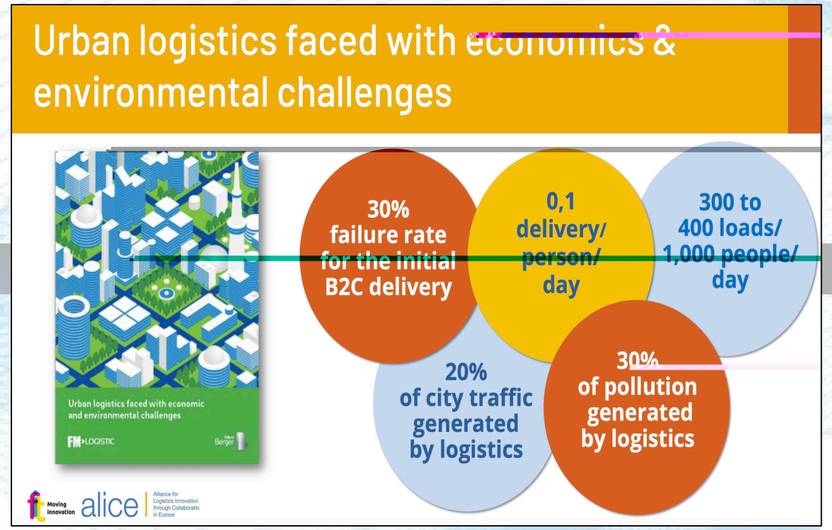


Source: United Nations (UN), 2018 Revision of World Urbanization Prospects

Source: Statista (Sep 2022)







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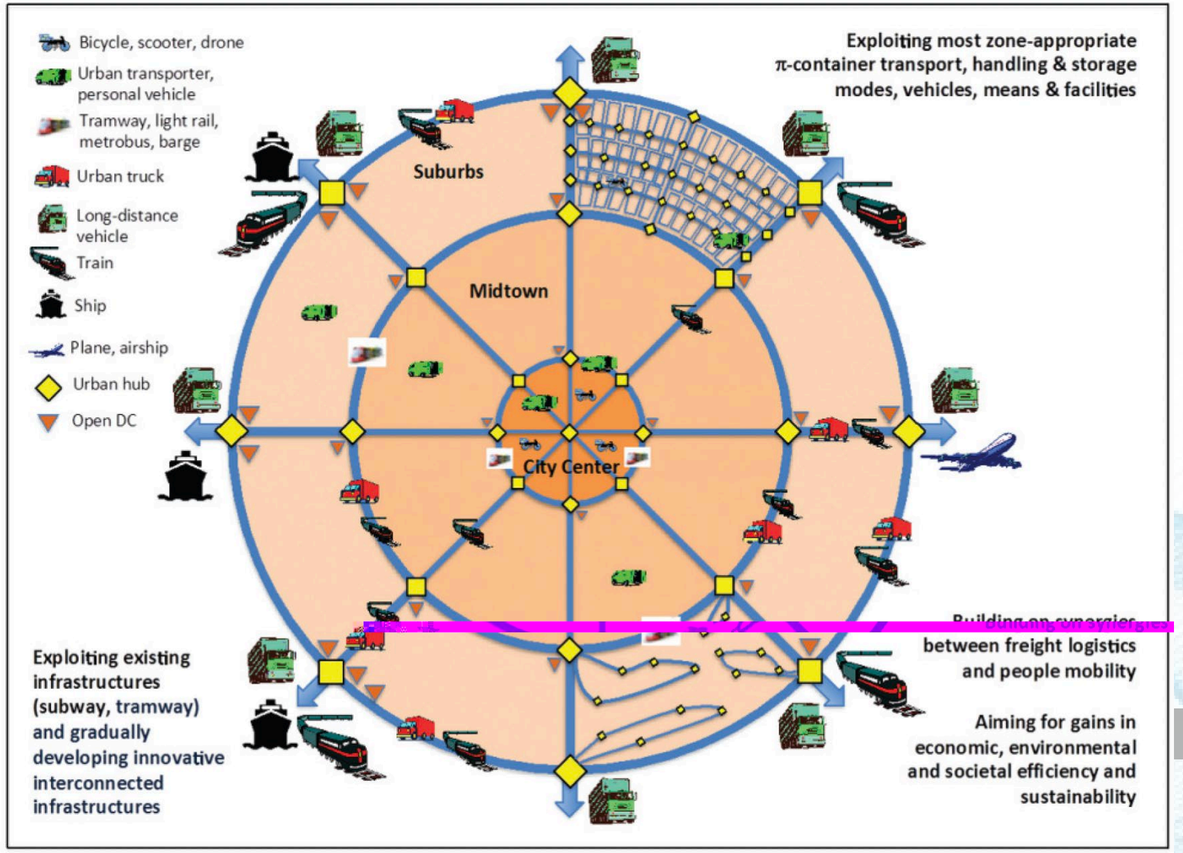
Hyperconnected City Logistics

Interconnect:

- Cities as nodes of the worldwide logistic web
- City logistic stakeholders into an open system via systems standardization
  - Coordination, Collaboration, Cooperation
- Multi-faceted activities of city logistics and urban planning
- Multiplicity of urban logistic centers
- City logistic networks into an urban web architecture



Source: Physical Internet Enabled Hyperconnected City Logistics (Crainic and Montreuil '16)

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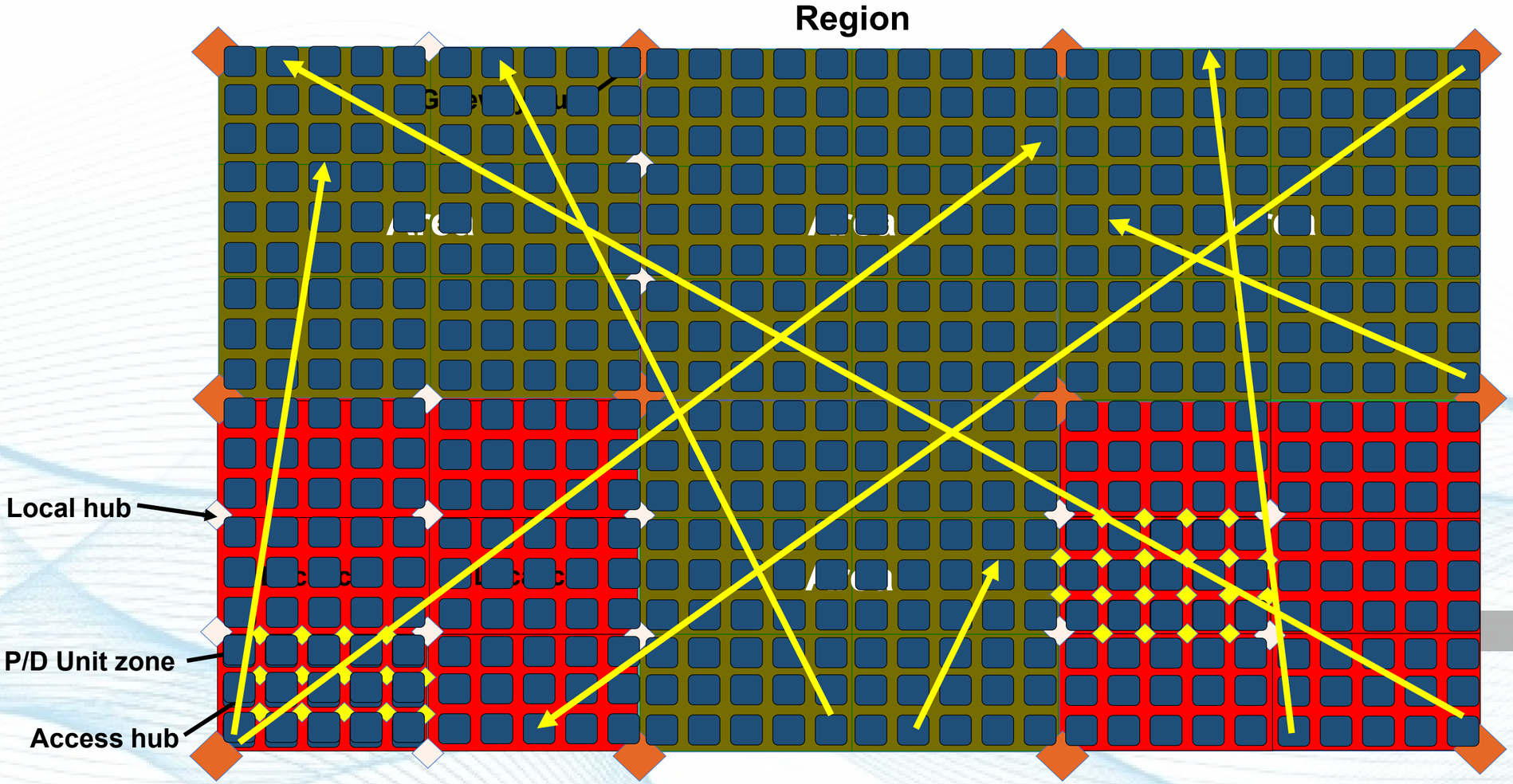
Hyperconnected Urban Logistic Network Topology



Urban city structures as a set of demand zones (mesh zones)

Origin-Destination (O-D) commodities with time requirements

Representative literature on Hyperconnected Multi-tier mesh networks

[Montreuil et al. ’18]
[Hettle et al. ‘21]
[Grover et al. ‘23]

Problem Definition

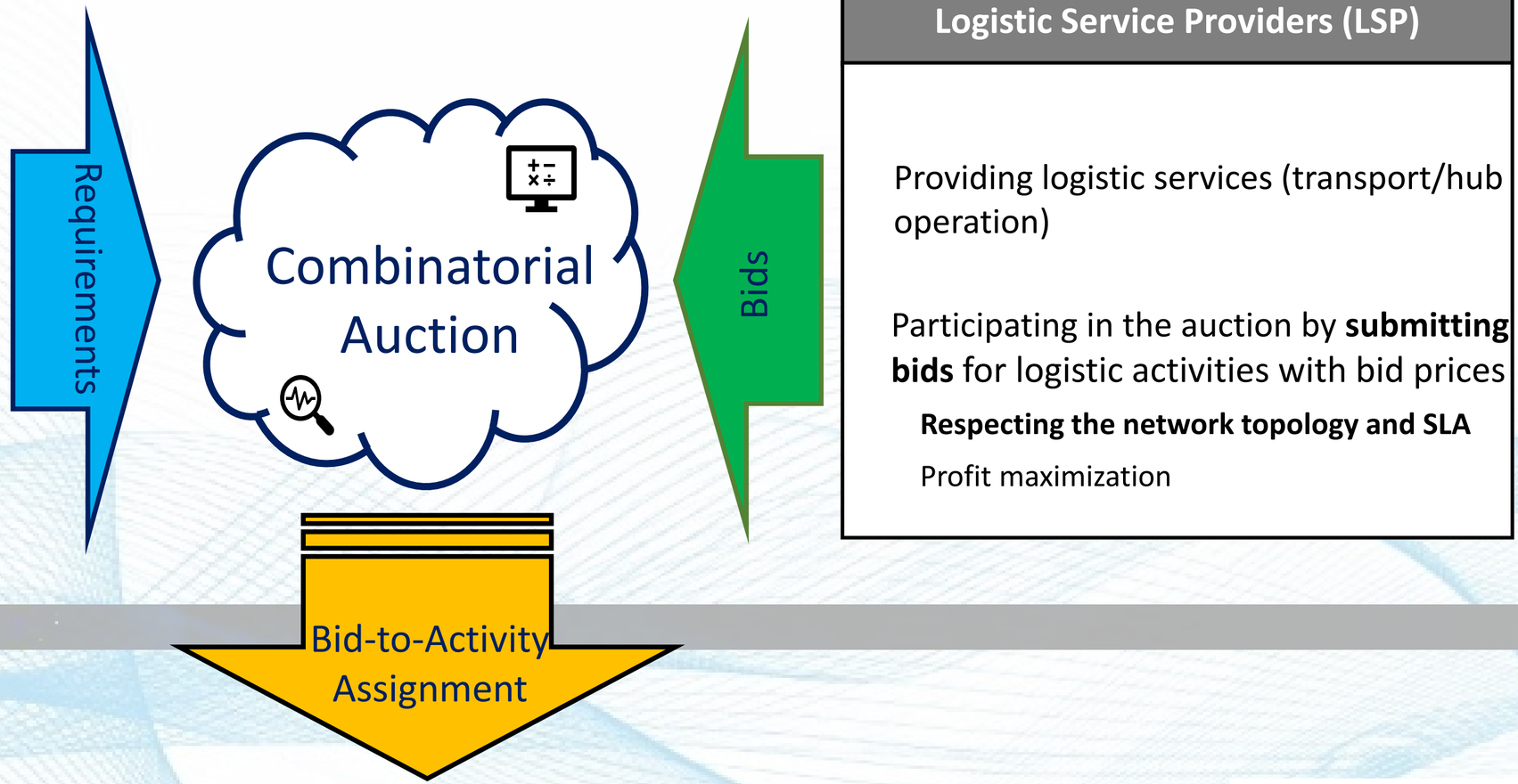
Logistic Orchestrator

Hyperconnected multi-tier network topology

- O-D service guarantees (e.g., x-hour delivery)

Multi-party coordination/orchestration via a **combinatorial auction**

- **Allocation of logistic activities to LSPs**
- Imposing **service level agreement (SLA) for each logistic activity**
- Robust O-D service guarantees in min. cost



Logistic Service Providers (LSP)

Providing logistic services (transport/hub operation)

Participating in the auction by **submitting bids** for logistic activities with bid prices

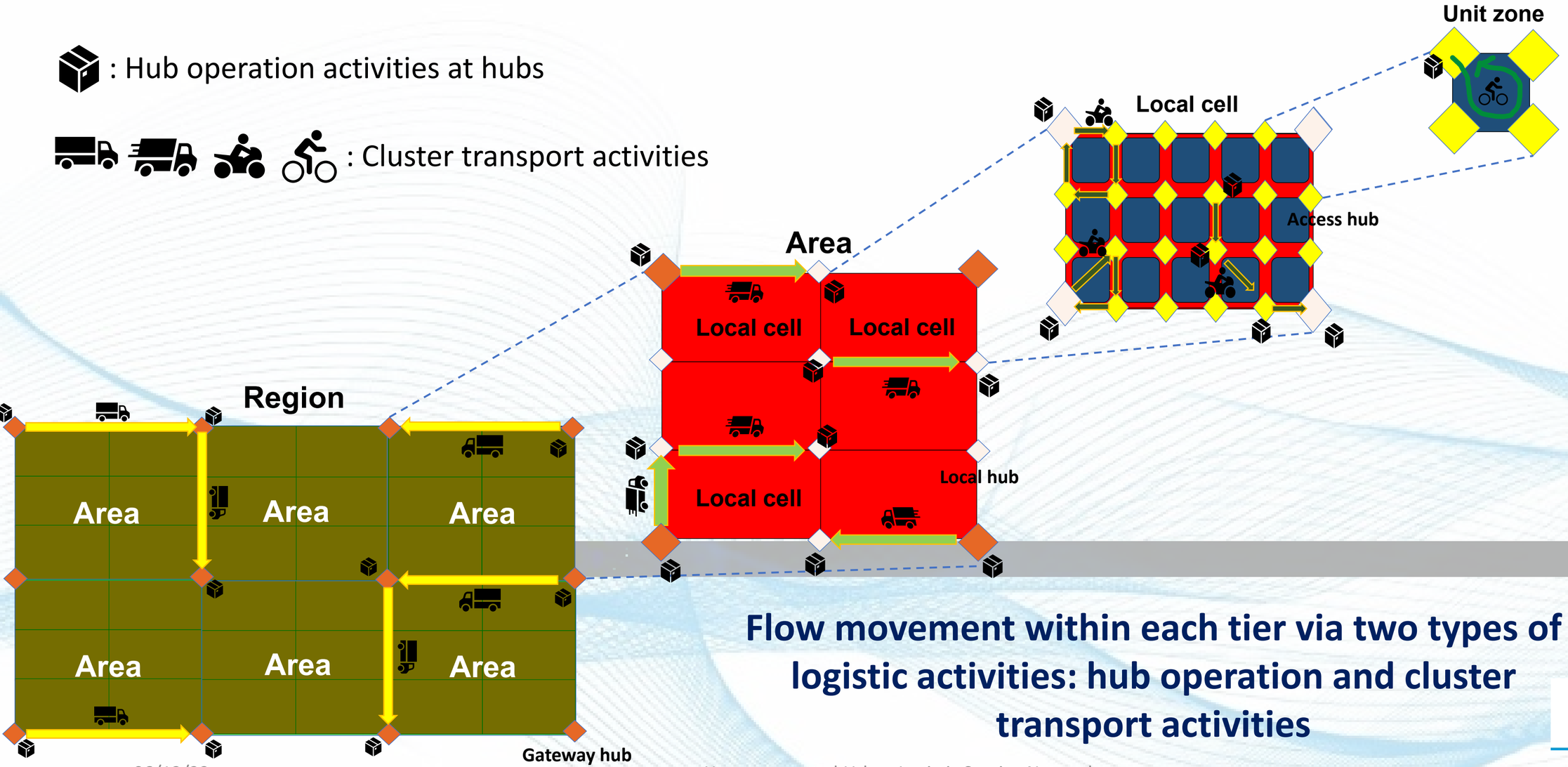
- **Respecting the network topology and SLA**
- Profit maximization

Optimized Service Networks

Logistic Activities in Hyperconnected Urban Logistic Network

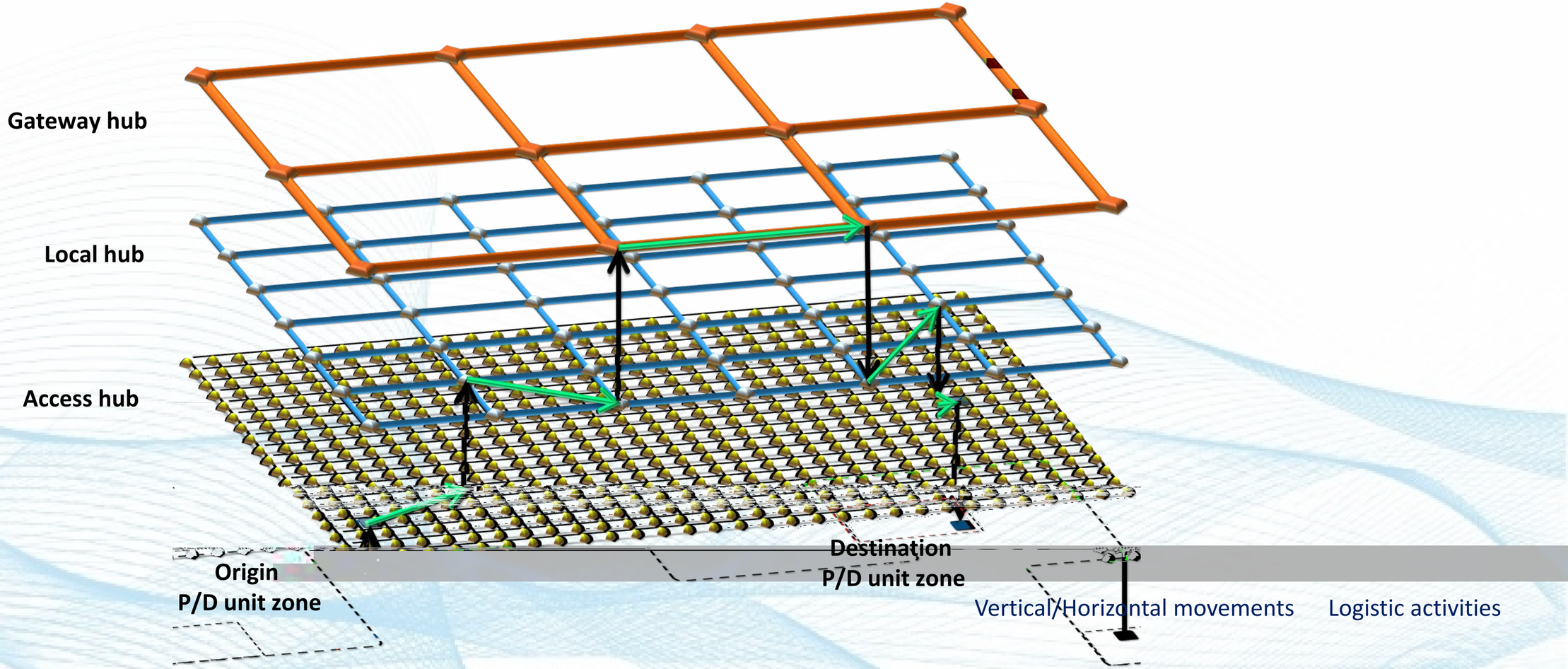
: Hub operation activities at hubs

: Cluster transport activities



Flow movement within each tier via two types of logistic activities: hub operation and cluster transport activities

Flow Movement Across the Proposed Networks



Origin-Destination flow movement across the networks through multiple planes via a set of logistic activities (cluster transport and hub operation activities)

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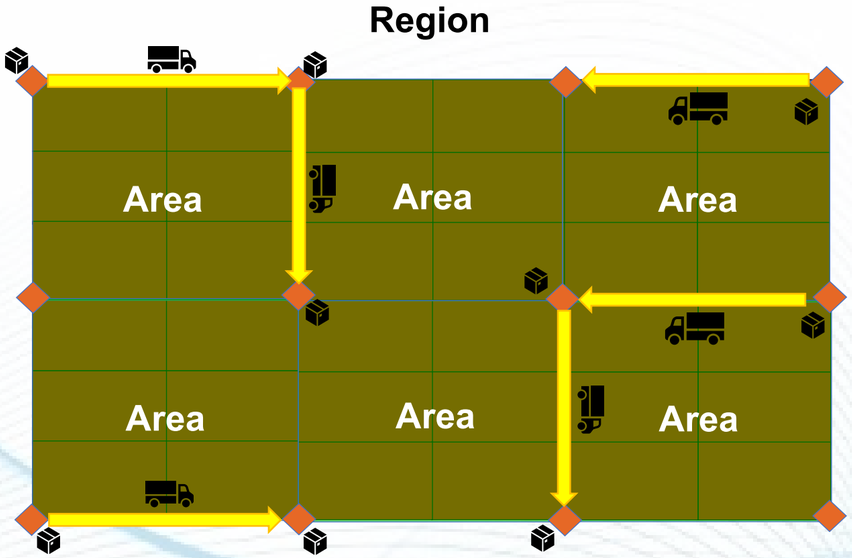
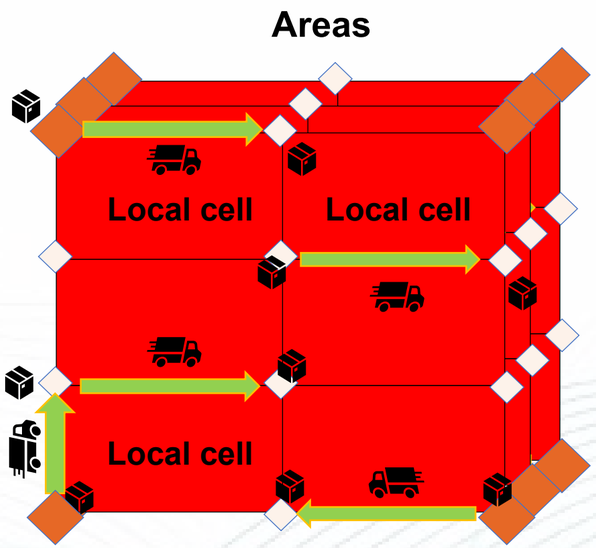
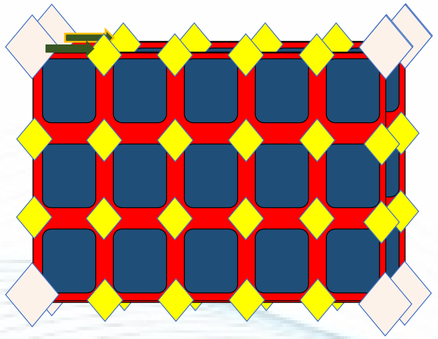
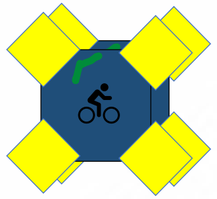
Service Level Agreement (SLA)

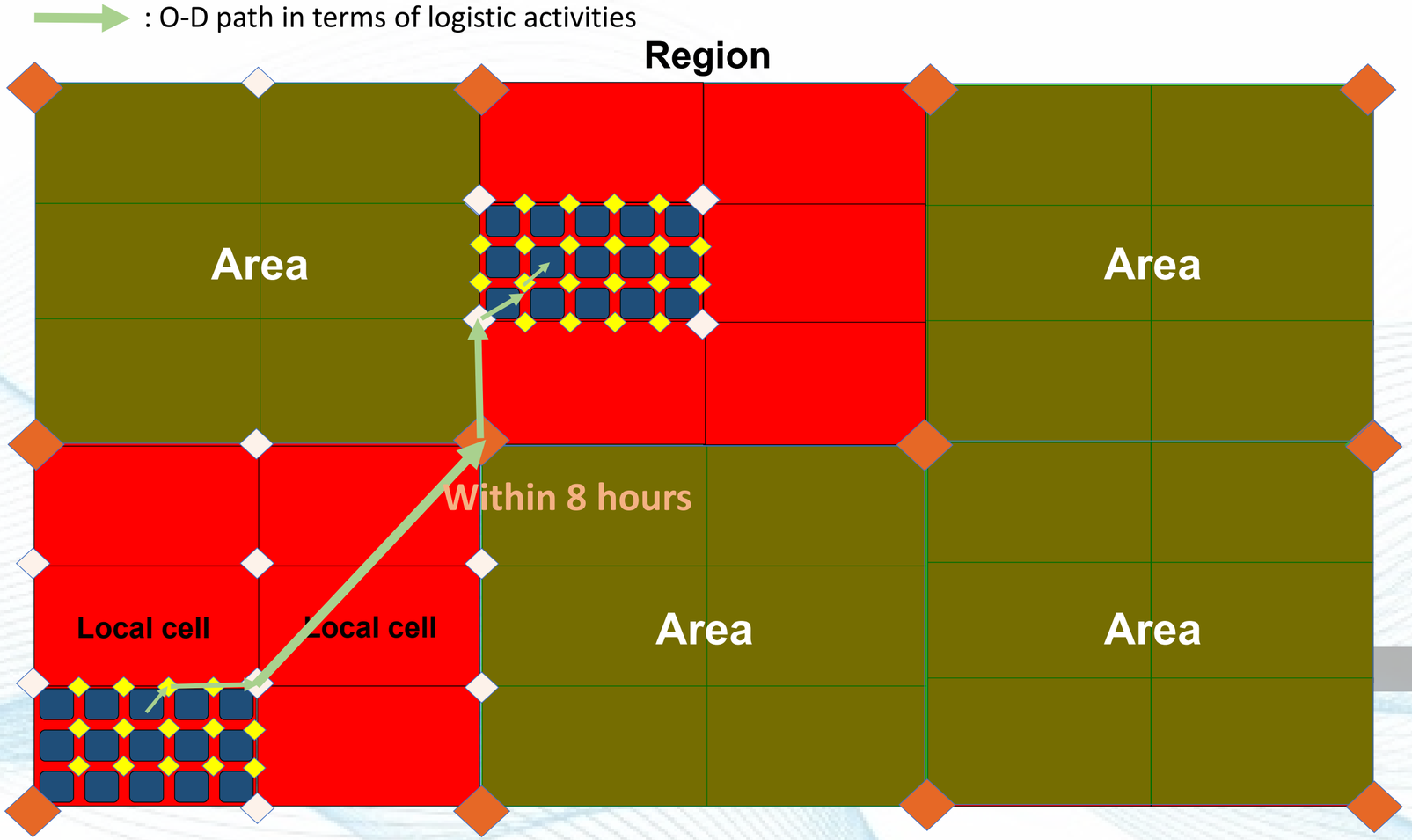








SLA Options for Logistic Activities by Logistic Orchestrator



Example of the movement of O-D commodity

Going through 11 logistic activities

6 cluster transport and 5 hub operation activities

Many combinatorial choices

Equally allocated
Proportional to volume/distance
…
Possibly too aggressive
High bid prices

Impact of SLA for activities on the overall cost

Requiring approximation of the reaction of bidders (LSPs)

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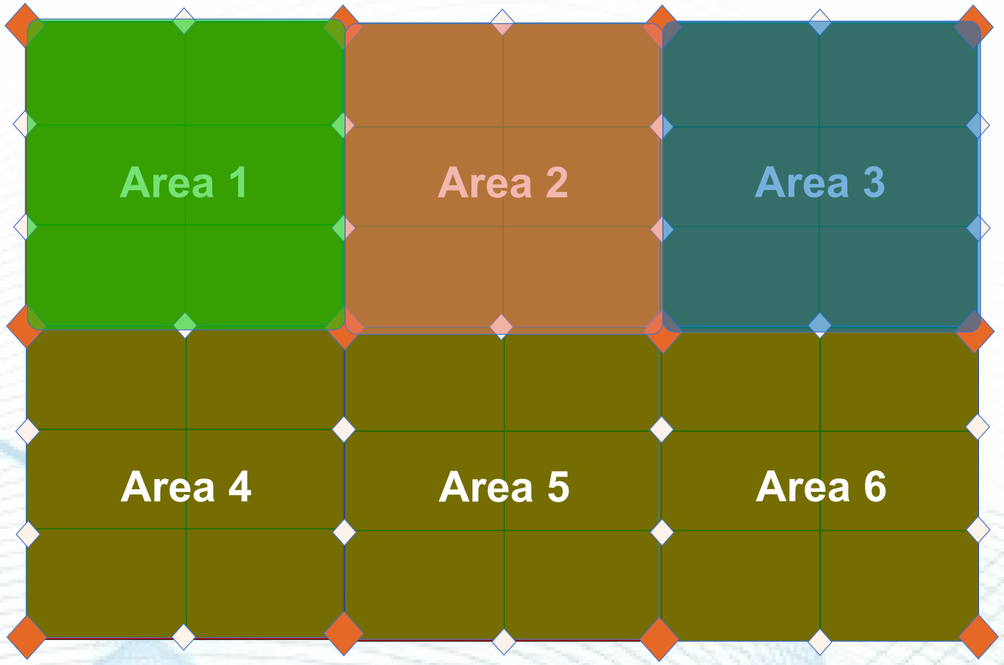
Bid Construction by Bidders (LSPs)

: Bidder 's bid
: Bid price of bid Bidder
Format of bids: {Activity(ies), , SLA}

SLA options for cluster transport activities for Areas 1-6 = {40, 60, 90 mins}



Bidder 1

: {Area 1, , 40 mins}
: {Area 2, , 60 mins}
: {Area 3, , 90 mins}

Set of single bids

Bidder 2

: { (Area 1, Area 2), , {40 mins, 40 mins}}
: { (Area 5, Area 6), , {60 mins, 40 mins}}

Set of bundle bids → Economies of scope, Better resource utilization

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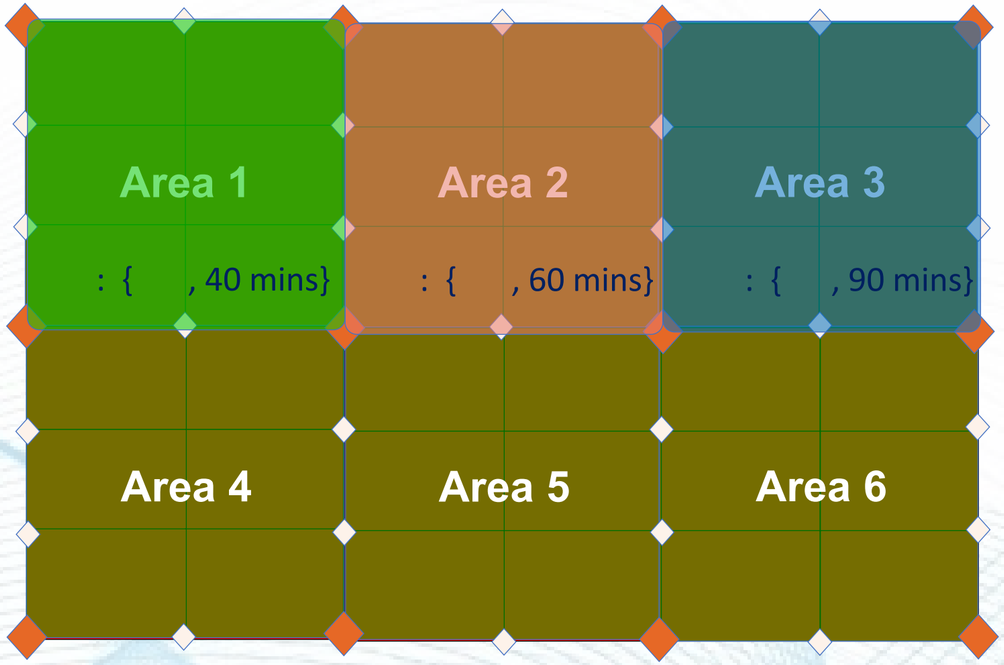
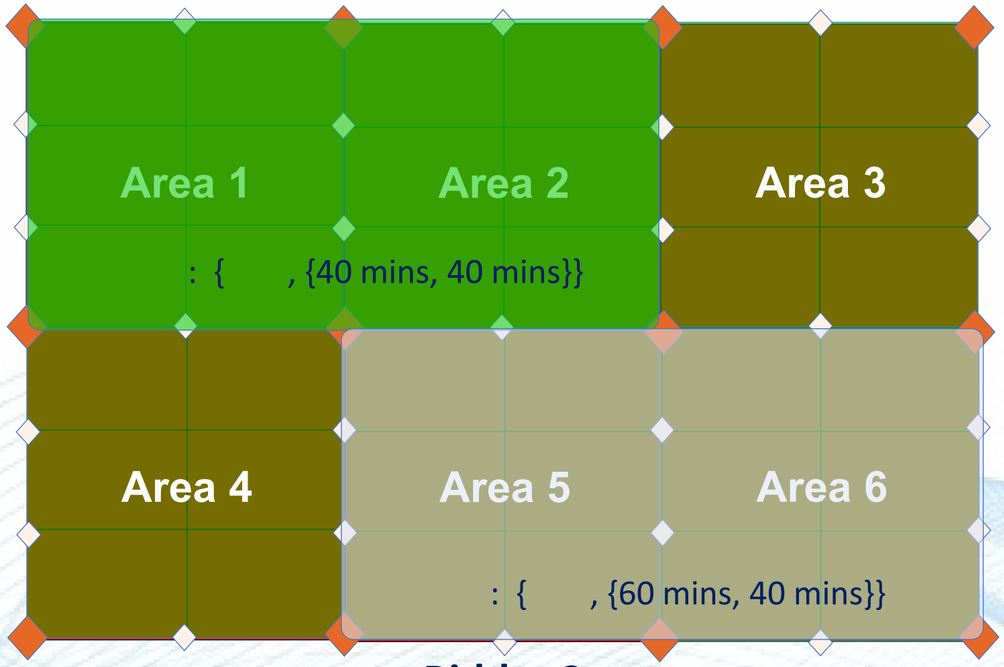
Bid Construction by Bidders (LSPs)

Submitted bids for Area transport activities by Bidders 1 and 2



Bidder 1



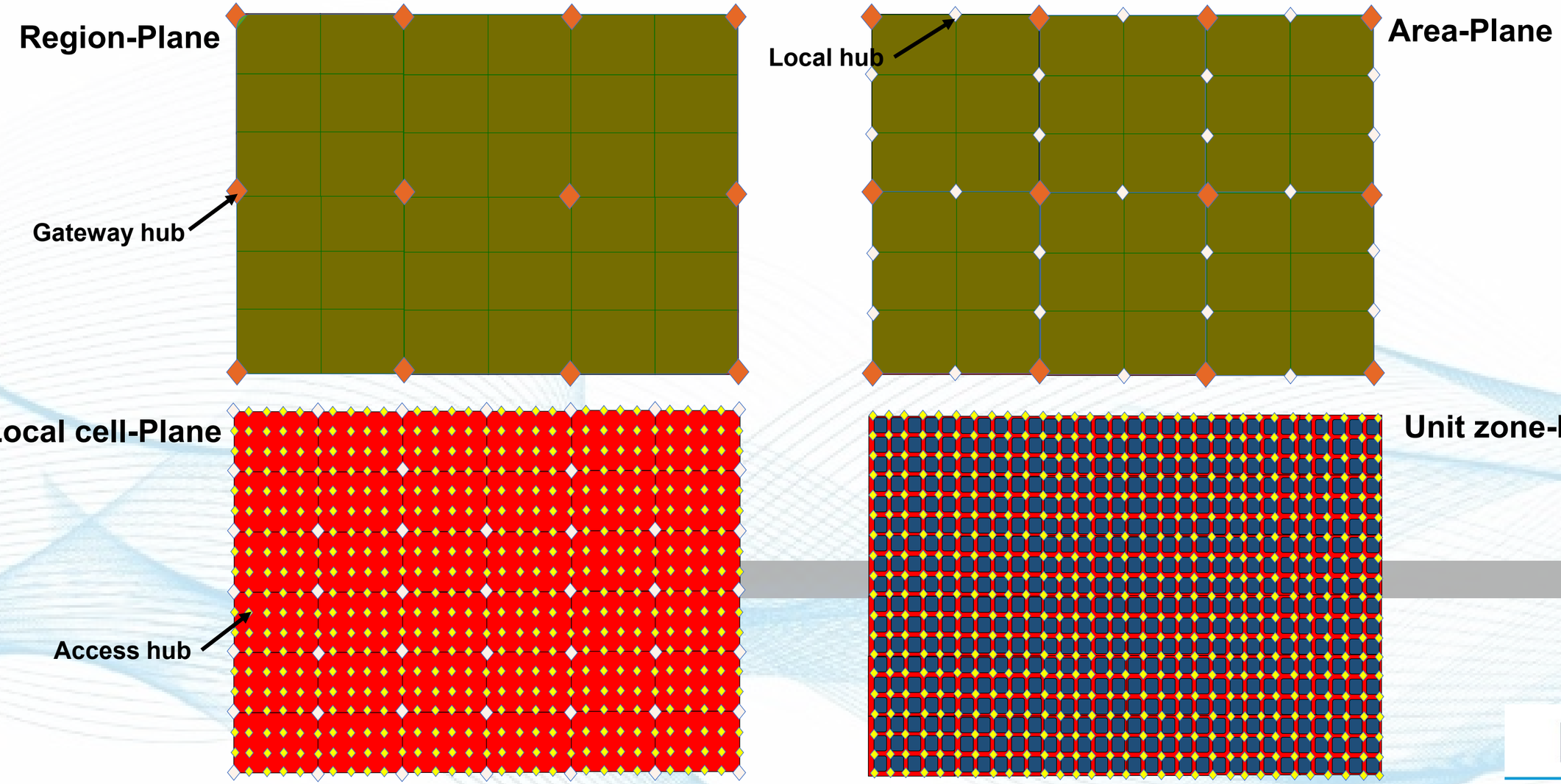
Bidder 2

Bid Price ( ) = Cost + Margin

Cost: Resource/Capacity, SLA

Margin: Competition, Willingness to pay

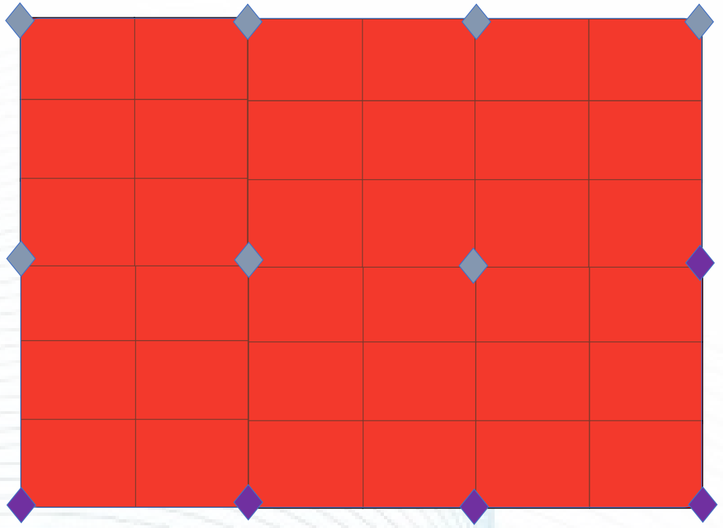
Bid-to-Activity Allocation



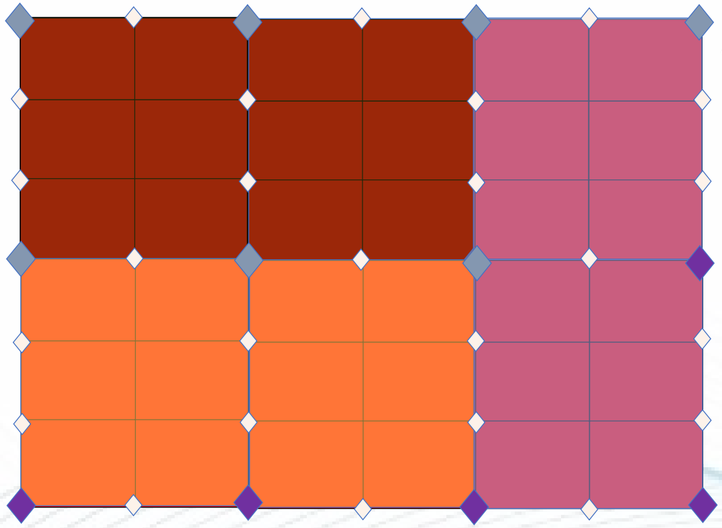
Bid-to-Activity Allocation

Optimized Service Network

Region-Plane

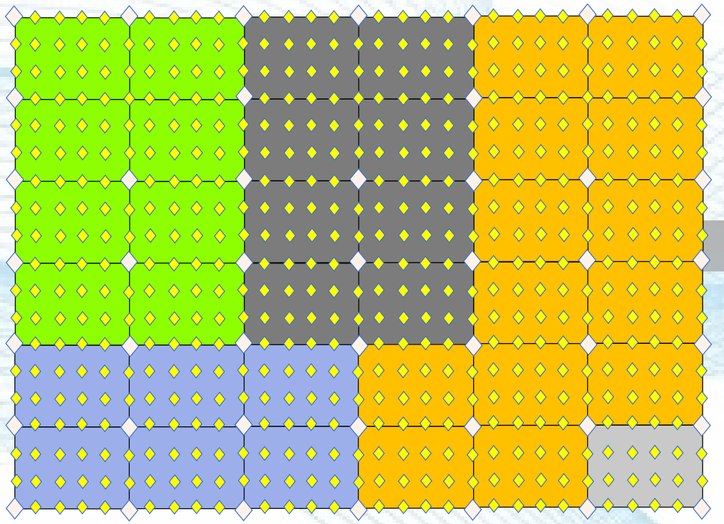


Area-Plane

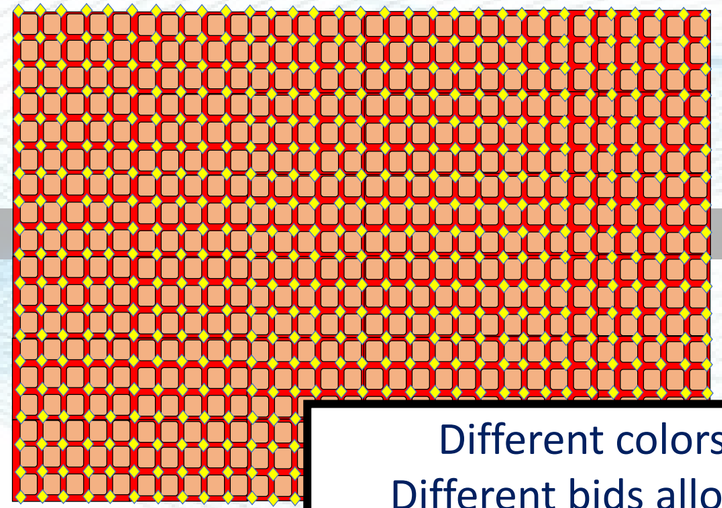


Case where all local hubs are allocated to one LSP (one bundle bid)

Local cell-Plane



Unit zone-Plane



Case where all unit zone transport activities and access hub activities are allocated to one LSP (one bundle bid), respectively

Different colors
Different bids allocated

Research Questions/Avenues

We consider a **first-price sealed-bid reverse combinatorial auction** in which **the logistic orchestrator** allocates each logistic activity to some specific **bidder** such that **the O-D service guarantees are robustly guaranteed** while minimizing cost

1st Phase by Logistic Orchestrator

Pre-auction stage

- Bid definition/requirements
- Network/Logistic activity Information

Service Level Agreement Offer Problem (SLAOP)

How to **determine a set of Service Level Agreement (SLA) options for each logistic activity**

2nd Phase by Bidders

Bid Construction Problem (BCP)

Which bids to submit when – under the uncertainty of other bidders' decisions and orchestrator's final decisions?

- Profit Maximization

3rd Phase by Logistic Orchestrator

Winner Determination Problem (WDP)

How to determine winning bids for each logistic activity and **which SLA to assign** each logistic activity

- Robust O-D service guarantees
- Cost Minimization

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Summary

Contributions:

New notion of the service network design problem in line with Physical Internet initiatives

Three-phased bidding-based design framework

Next steps:

Optimization, Simulation, and Game theoretic techniques for each Phase

- Approximation of reaction of other players
- Capturing competition and uncertainty
- Robust O-D service guarantees

Thank you!

Questions: skwon82@gatech.edu