Georgia Tech Physical Internet Center
Stewart School of Industrial & Systems Engineering

The Physical Internet: Shaping a Global Hyperconnected Logistics Infrastructure

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Physical Internet

Hyperconnected global logistics system

enabling seamless open asset sharing and flow consolidation

through standardized encapsulation, modularization, protocols and interfaces

to improve the capability, efficiency and sustainability of serving humanity's demand for physical objects

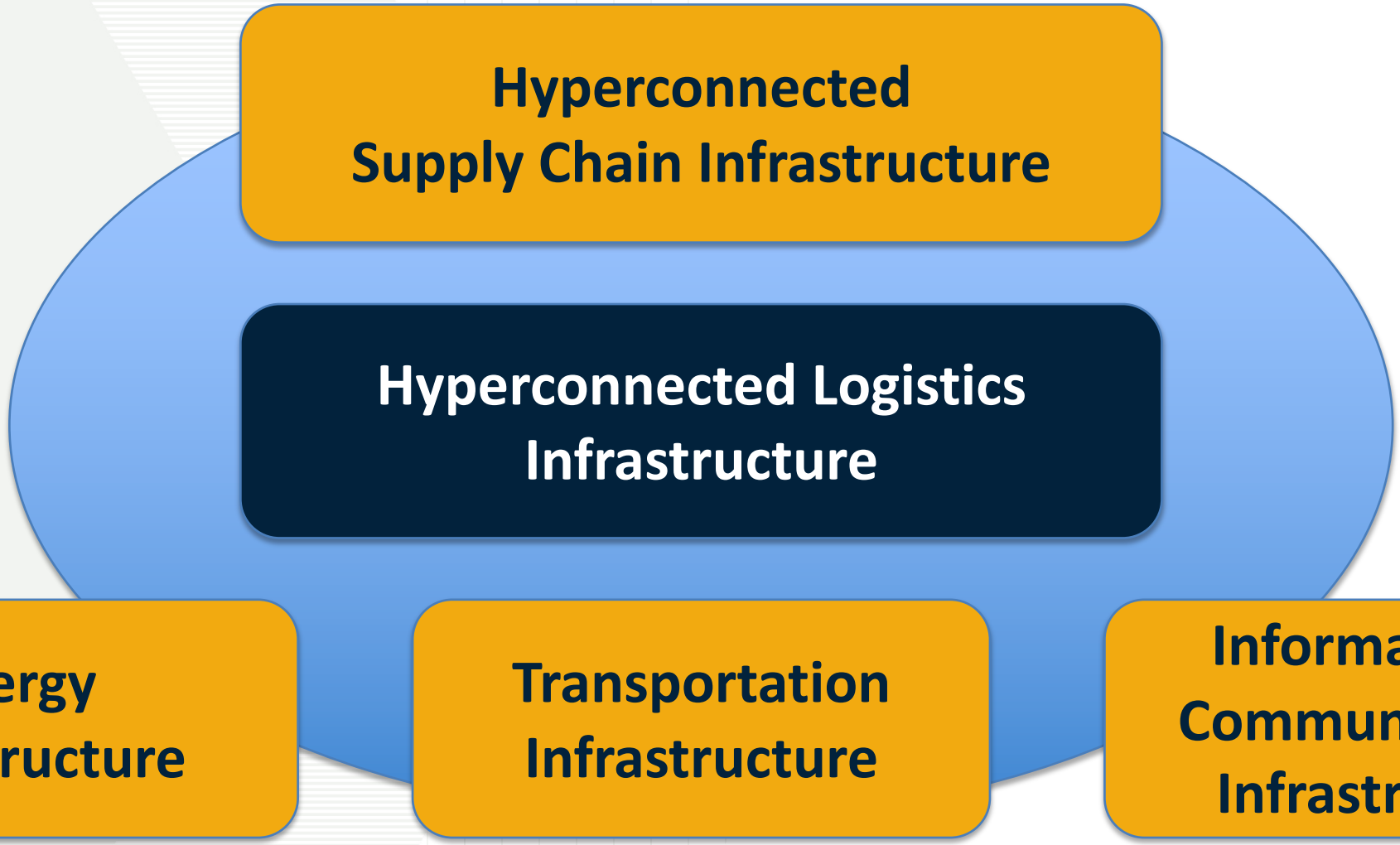
Image source: clyderathbone.com

Hyperconnected:
Components and actors intensely interconnected on multiple layers, ultimately anytime, anywhere

Interconnectivity layers:
digital, physical, operational, business, legal and personal

Definition by B. Montreuil, International Physical Internet Conference, Keynote Presentation, July 2015;

PI Induced Hyperconnected Logistics Infrastructure



Smart Grid, Fuel & Charging Distribution

Roads, Ports, Railways, …

Digital Internet, Internet-of-Things

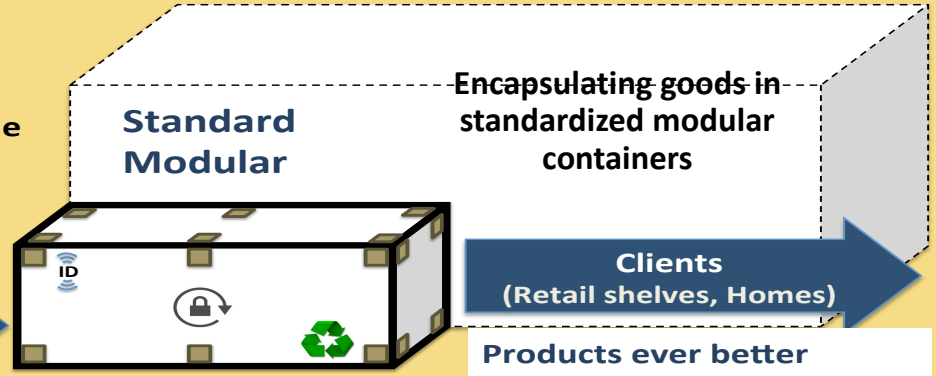
Hyperconnected Logistics Infrastructure

Ubiquitous Modular Containerization

Easy to Handle, Store & Transport
- Robust & reliable
- Snap and interlock
- Load and unload
- Seal and unseal
- Compose & decompose
- Conditioning capable
- Cleanable
- *Panel (pub + info)*

Smart & Connected
- Uniquely identifiable
- Communications capable
- State memory
- *Reasoning capabilities*

Eco-friendly
- Light & thin
- Reusable and/or recyclable
- Minimal off-service footprint
- Distinct structural grades

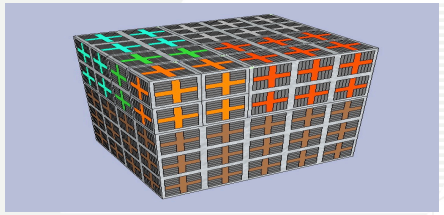


- Private nest in an open space
- Used throughout the Physical Internet
- Owned by producer, pooler, logistic service provider, or user
- Transacted on the spot as pertinent
- No need to return to source
- Reused numerous times
- Drastically eases handling activities

Packaging Containers (Packs)

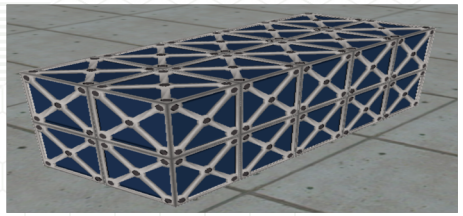
Modular fit in Boxes
1,2; 0,8; 0,6; 0,4; 0,3; 0,2; 0,1 – ε - δ meters

Handling Containers (Totes, Boxes)



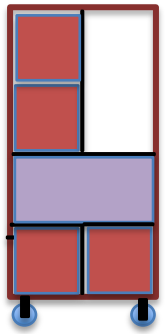
Modular fit in Pods
Boxes: 1,2; 0,8; 0,6 – ε meters
Totes: 0,6; 0,4; 0,3; 0,2; 0,1 – ε' meters

Transport Containers (Pods)



Modular fit in certified vehicles-carriers
12; 6; 4,8; 3,6; 2,4; 1,2 meters

Mobile Racks (unitizing handling containers



Modular fit in pods
Same footprint as boxes

Hyperconnected Logistics Infrastructure
Open-Access, Shared, Fast-Response, Agile Facilities

Production Fabs

Making
Dis/Assembling
Recycling
Processing

Factories
Assembly centers
Personalization Centers
3D Printing Centers
Recycling Centers

Deployment Centers

Objects not yet requested by customer / user, prepositioned for convenient demand fulfilment

Warehouses, Depots
Mixing Centers
Distribution Centers
Fulfillment Centers

Logistics Hubs

Ordered objects on their way to destination

Consolidating
Crossdocking
Sorting, Swapping
Transshipping

Transit Hubs
Crossdocking Hubs
Delivery Hubs
Airports, Railyards, Ports
Multimodal Hubs

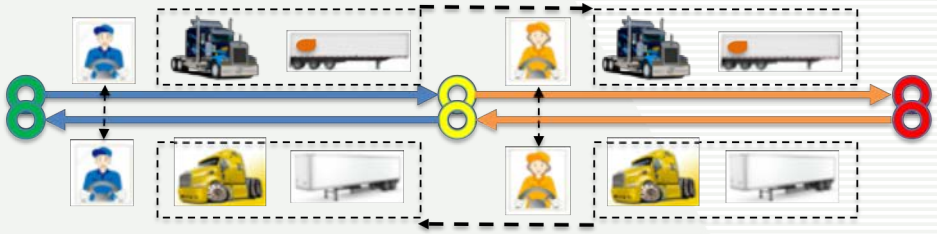
Customer Interfaces

Showcasing
Trying
Purchasing
Picking
Returning

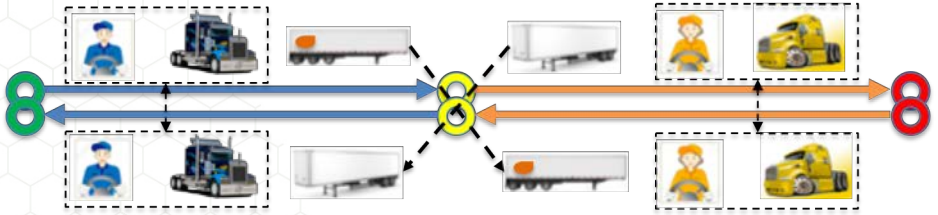
Retail stores
Smart Lockers
Click-&-Collect Drives

Focus on Logistic Hub Capabilities
Synchronous and/or Asynchronous Extramural Activities

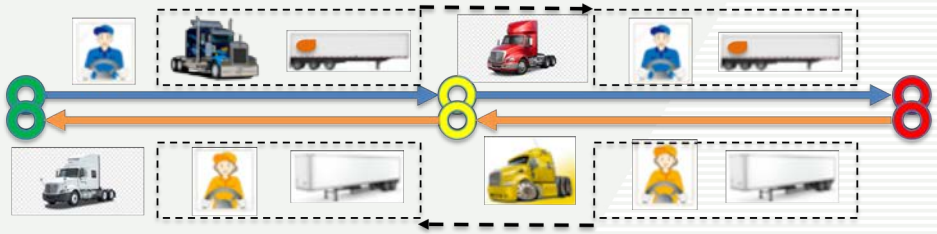
Driver Swapping



Carrier Swapping (semi-trailer, railcar…)



Tractor Swapping (e.g. trucks needing to recharge)



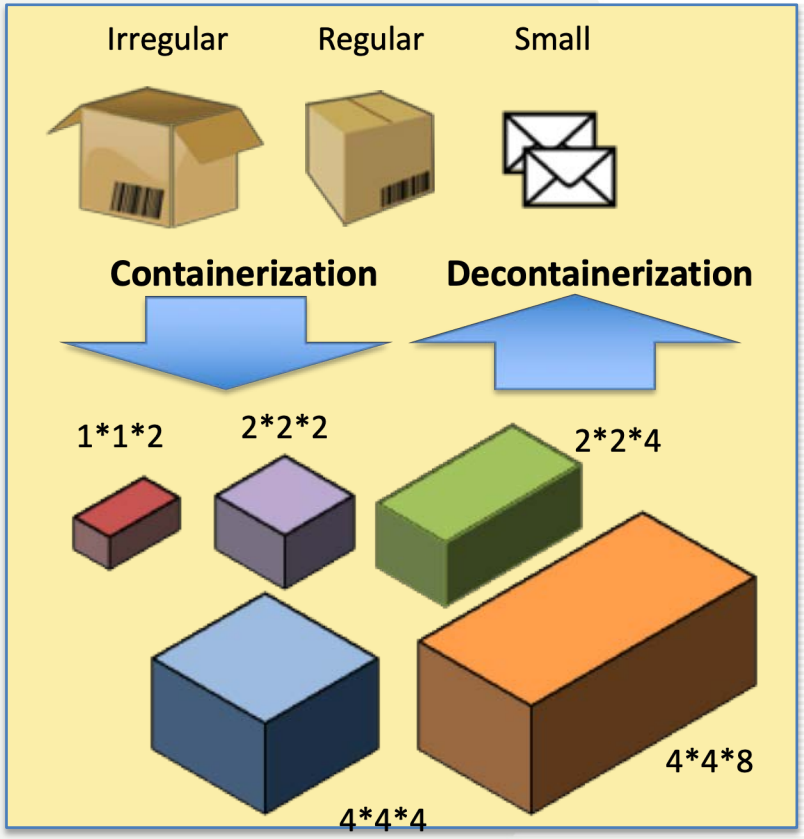
Transport Container Transshipment (unimodal or intermodal)

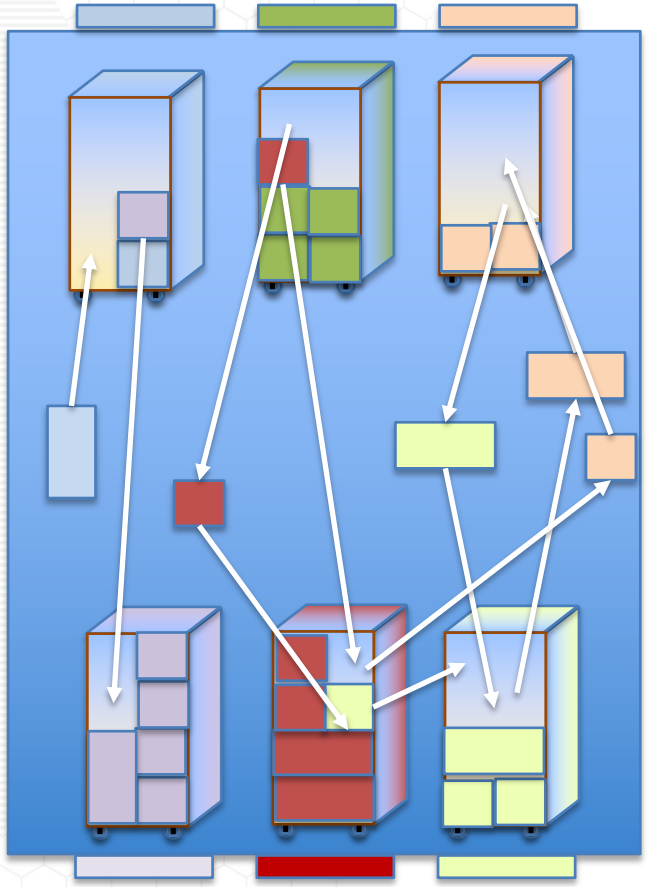
Tractor parking, fueling, charging, servicing
Driver waiting, eating, resting, cleaning

Carrier parking, servicing
Container parking, servicing

Focus on Logistic Hub Capabilities
Synchronous and/or Asynchronous Intramural Consolidation Activities

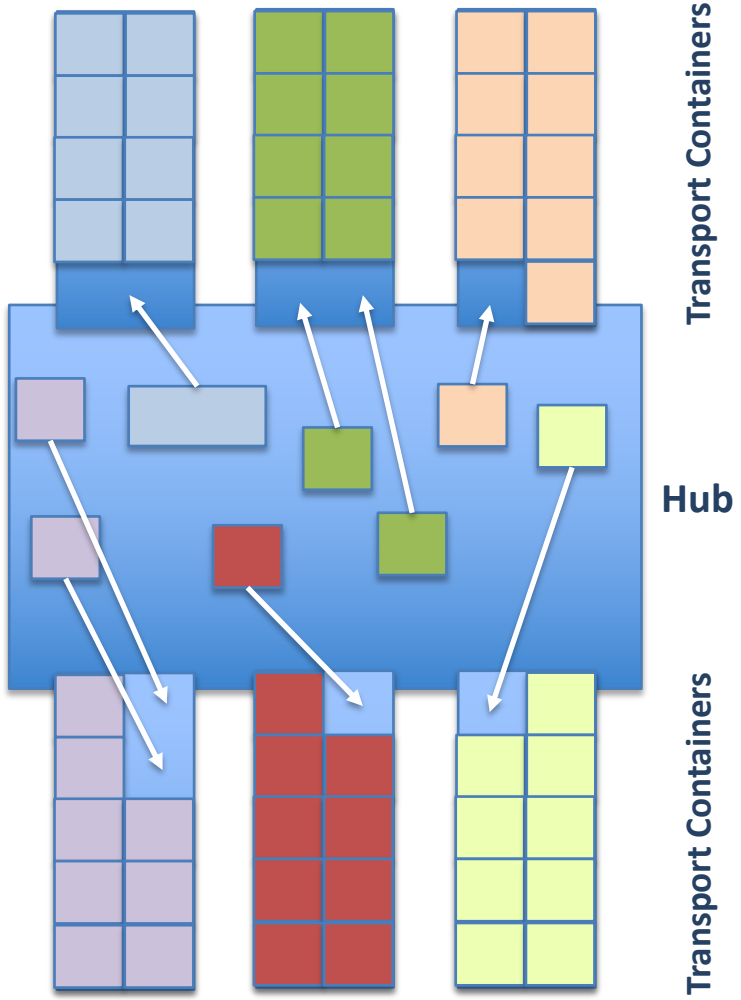
Goods De/Containerization & Sorting





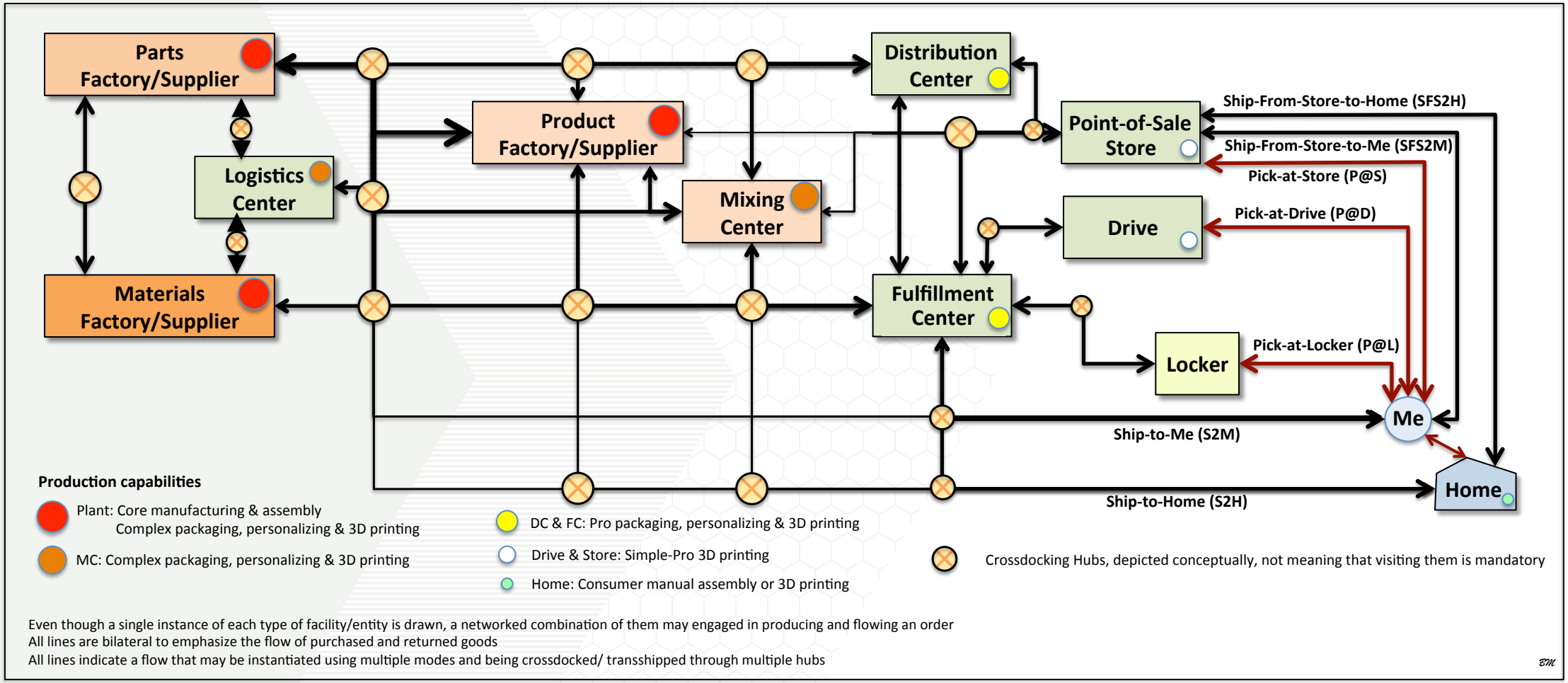
Handling Container Reshuffling

Handling Container & Rack Crossdocking



Hyperconnected E-Commerce & Omnichannel Logistics Infrastructure

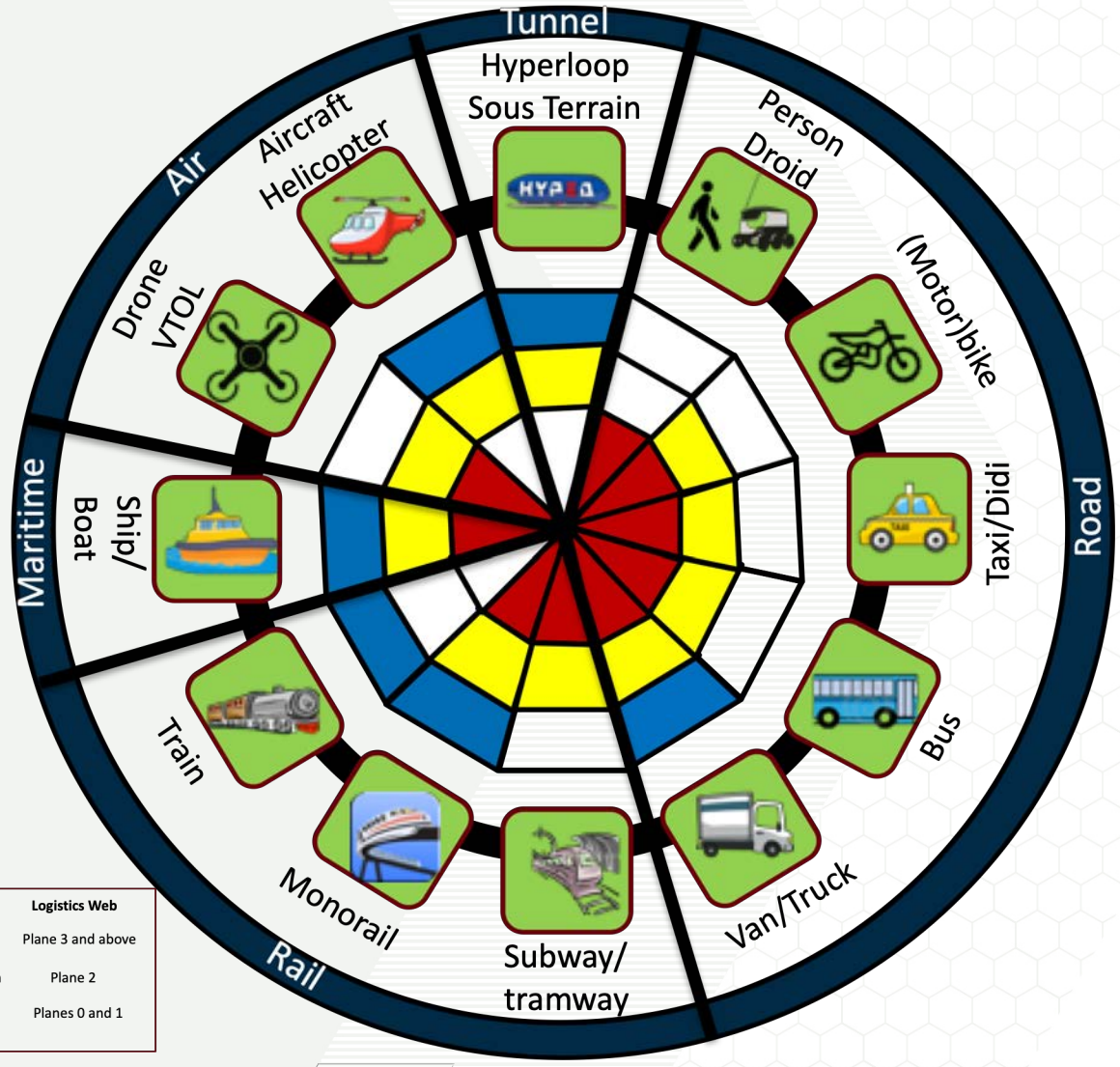
Open Asset Sharing & Flow Consolidation Essential to Sustainably Meet Expectations



Expected Convenient and Reliable Delivery or Pickup with Minutes, Hours, maybe a few Days
With Minimal Stock Smartly Flowed and Deployed Between Suppliers and Customers

Montreuil B. (2017). *Omnichannel Business-to-Consumer Logistics and Supply Chains: Towards Hyperconnected Networks and Facilities*, **Progress in Material Handling Research Vol. 14**, Ed. K. Ellis et al., MHI, Charlo[illegible], NC, USA.
CMO Innovation, 2015-09-02, http://www.enterpriseinnovation.net/sponsor-article/art-and-science-omni-channel-retailing http://www.wilsonperumal.com/blog/can-97-of-retailers-be-wrong-about-omni-channel-commerce/

Hyperconnected Logistics Infrastructure
Enabling Multimodal and Omnisource Transportation



Code	Range	Logistics Web
	Long	Plane 3 and above
	Medium	Plane 2
	Short	Planes 0 and 1

OMNISOURCE TRANSPORTATION

Smart Dynamic Leveraging

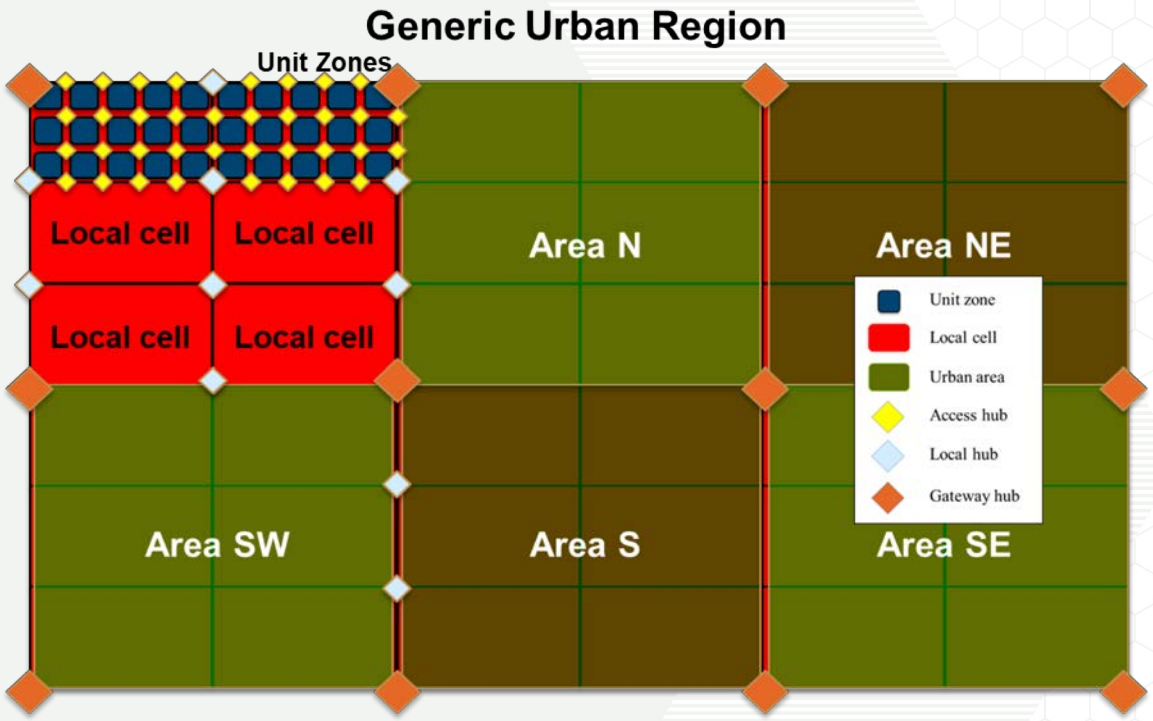
Dedicated Fleet (Own & Partners)	Smart Contracts with Service Providers	On-Demand Spot Market Crowdsourcing

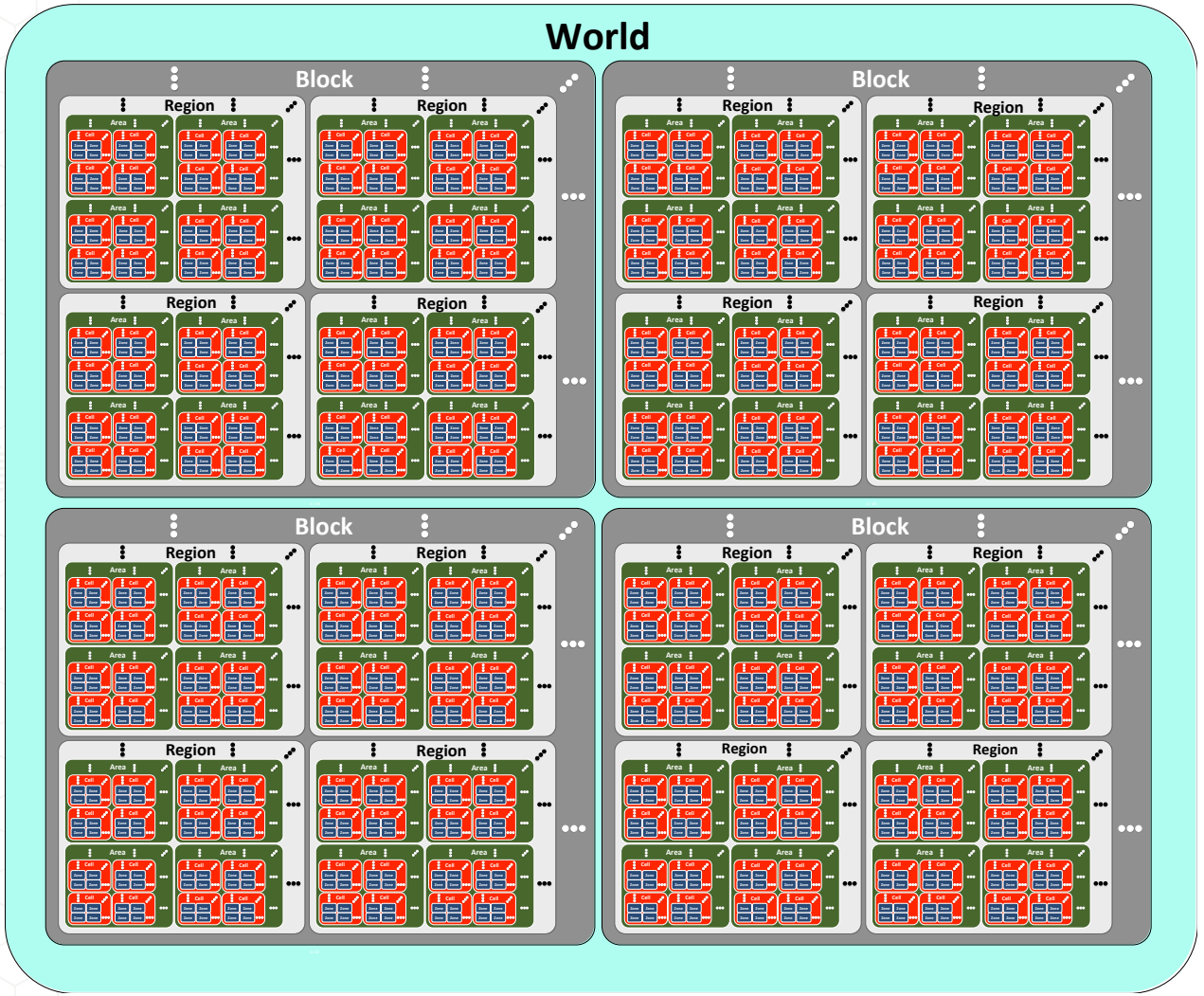
Multimodal Transport	Multi-Size Vehicle-Carrier

Coping with
Time and Price Sensitivity of Customers
Demand Variability and Uncertainty

Economic, Environmental & Societal Sustainability

Hyperconnected Logistics Infrastructure
Dynamically Managed Multi-Tier Logistics Space Structure

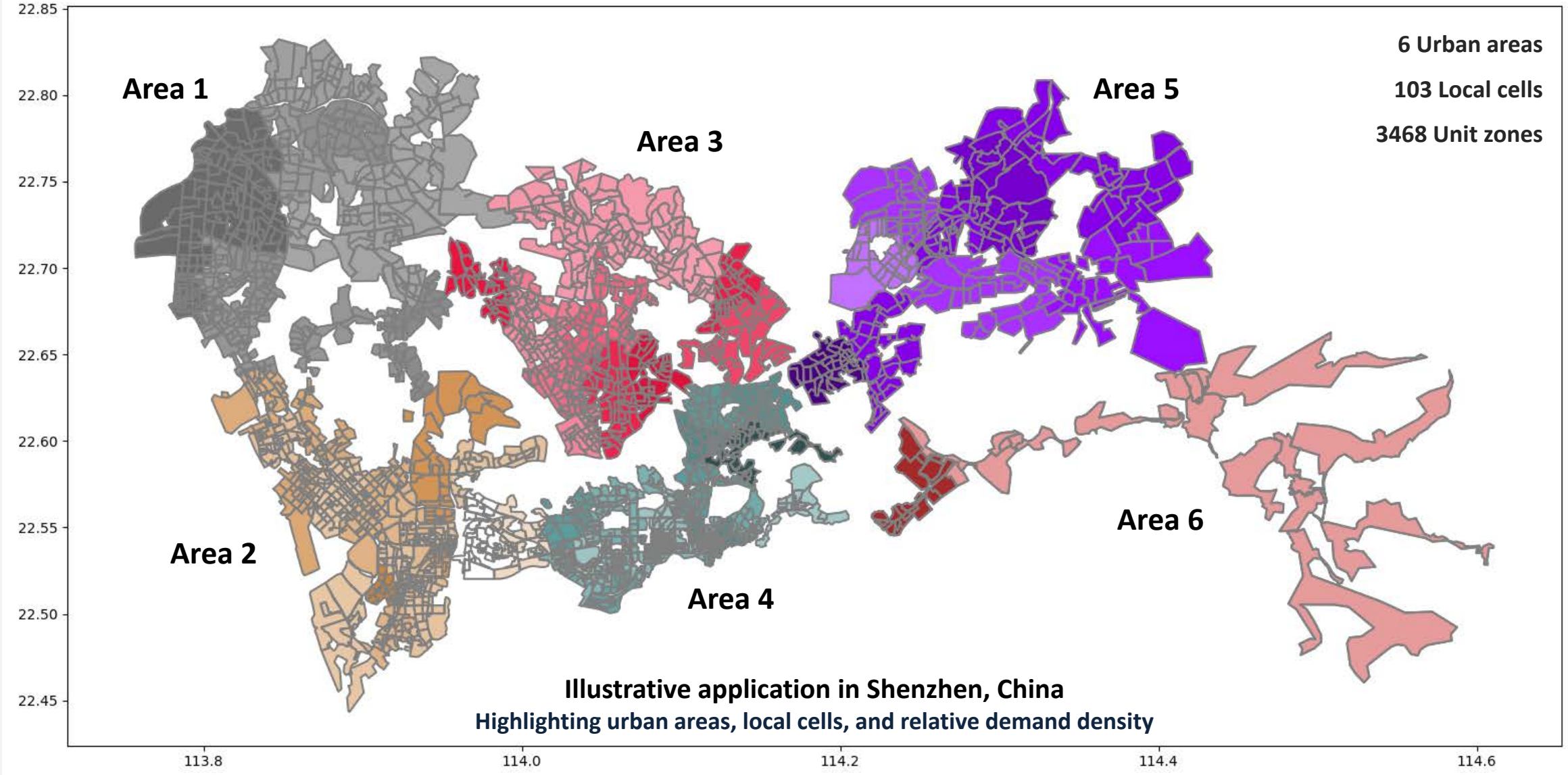




- Expanding on the notions of postal / zip codes
- Needs multi-party authoritative agreement
- Focus on logistics purposes, in harmony with others
- Evolutive with demand and logistics patterns & density

Adapted and extended from Montreuil B., S. Buckley, L. Faugere, K. Reem, S. Derhami, (2018). *Urban Parcel Logistic Hub and Network Design: The Impact of Modularity and Hyperconnectivity*, in **Progress in Material Handling Research, Vol. 15**, MHI, Charlotte, NC, USA, 8 p., 2018.

Urban Space Structuring: Urban Areas in Megacity

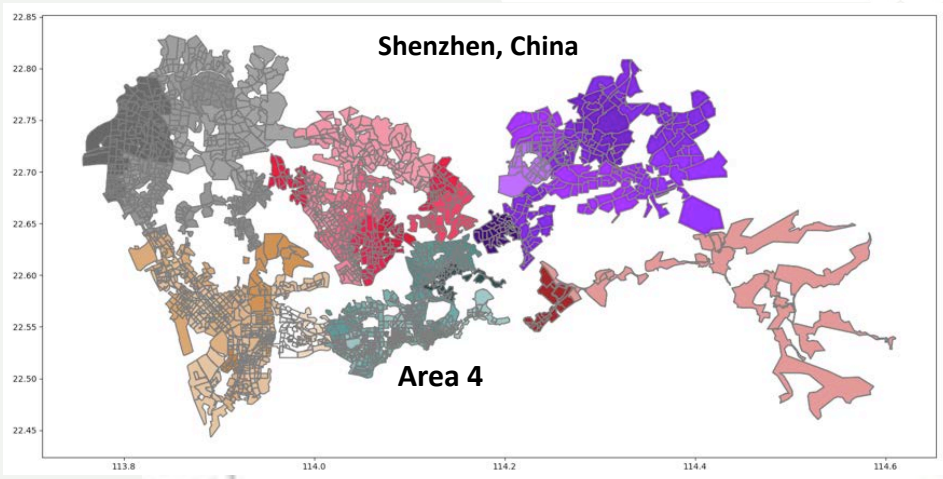


Illustrative application in Shenzhen, China

Highlighting urban areas, local cells, and relative demand density

Space clustering created by Ph.D. student Simon Kwon and Professor Benoit Montreuil for illustrative and benchmarking purposes: it is not meant to be prescriptive

Urban Space Structuring: Local Cells in an Urban Area



1 Urban area

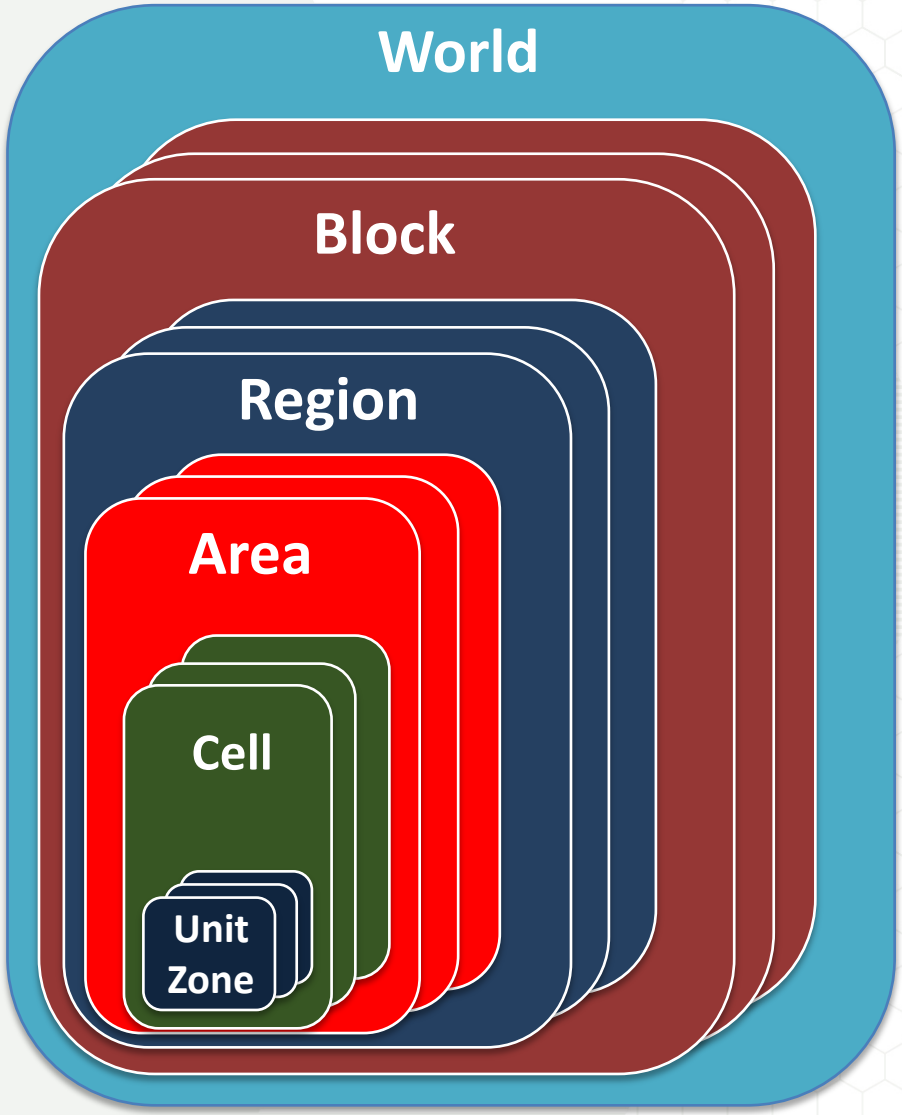
37 Local cells

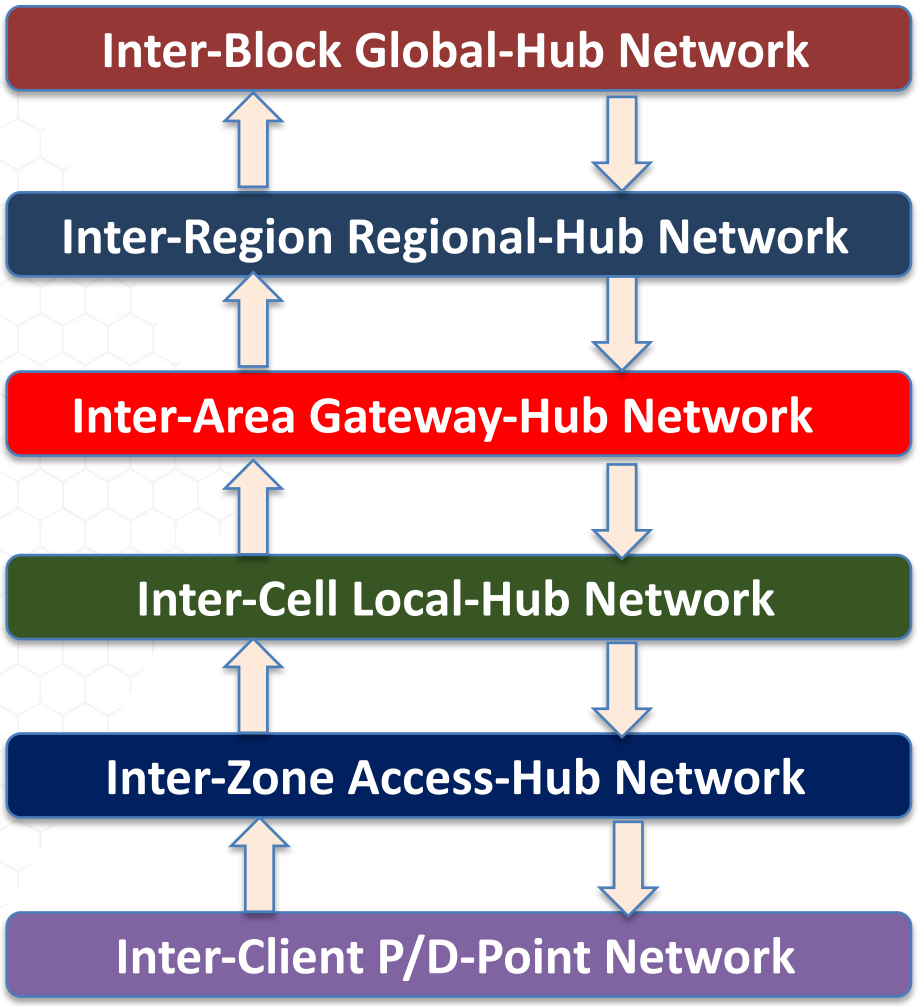
1189 Unit zones

Urban Area 4
Shenzhen, China

Space clustering created by Ph.D. student Simon Kwon and Professor Benoit Montreuil for illustrative and benchmarking purposes: it is not meant to be prescriptive

Hyperconnected Logistics Infrastructure
Logistics Web with Multi-Plane Mesh Networks





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Hyperconnected Logistics Infrastructure
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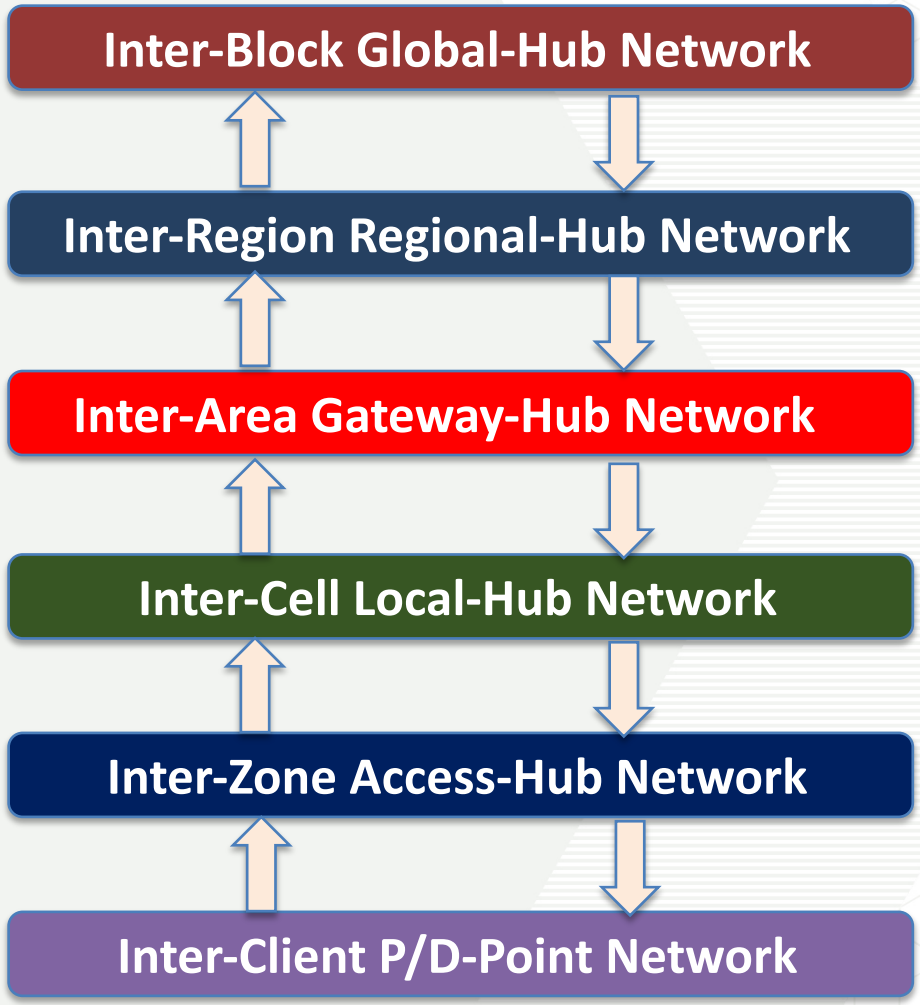
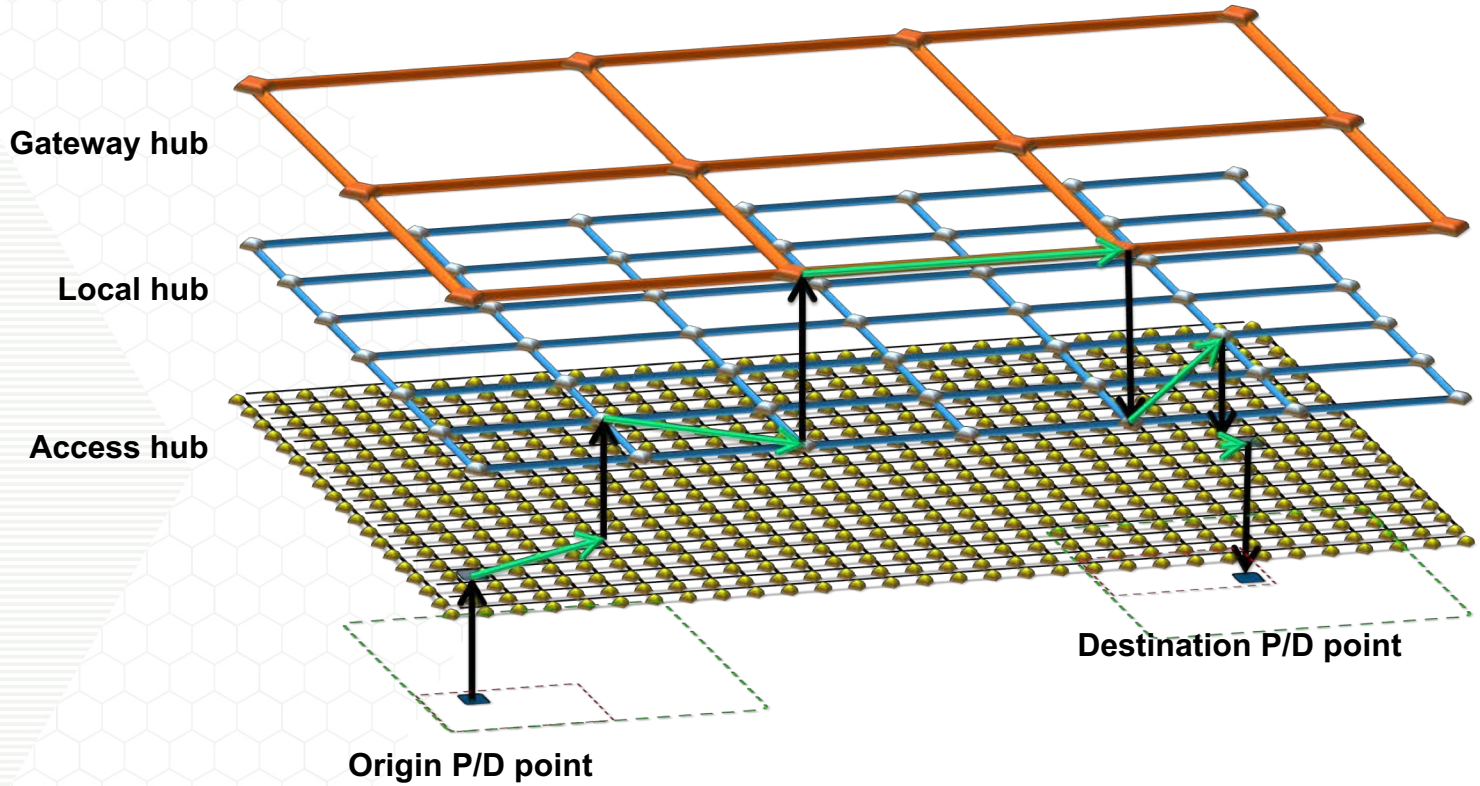
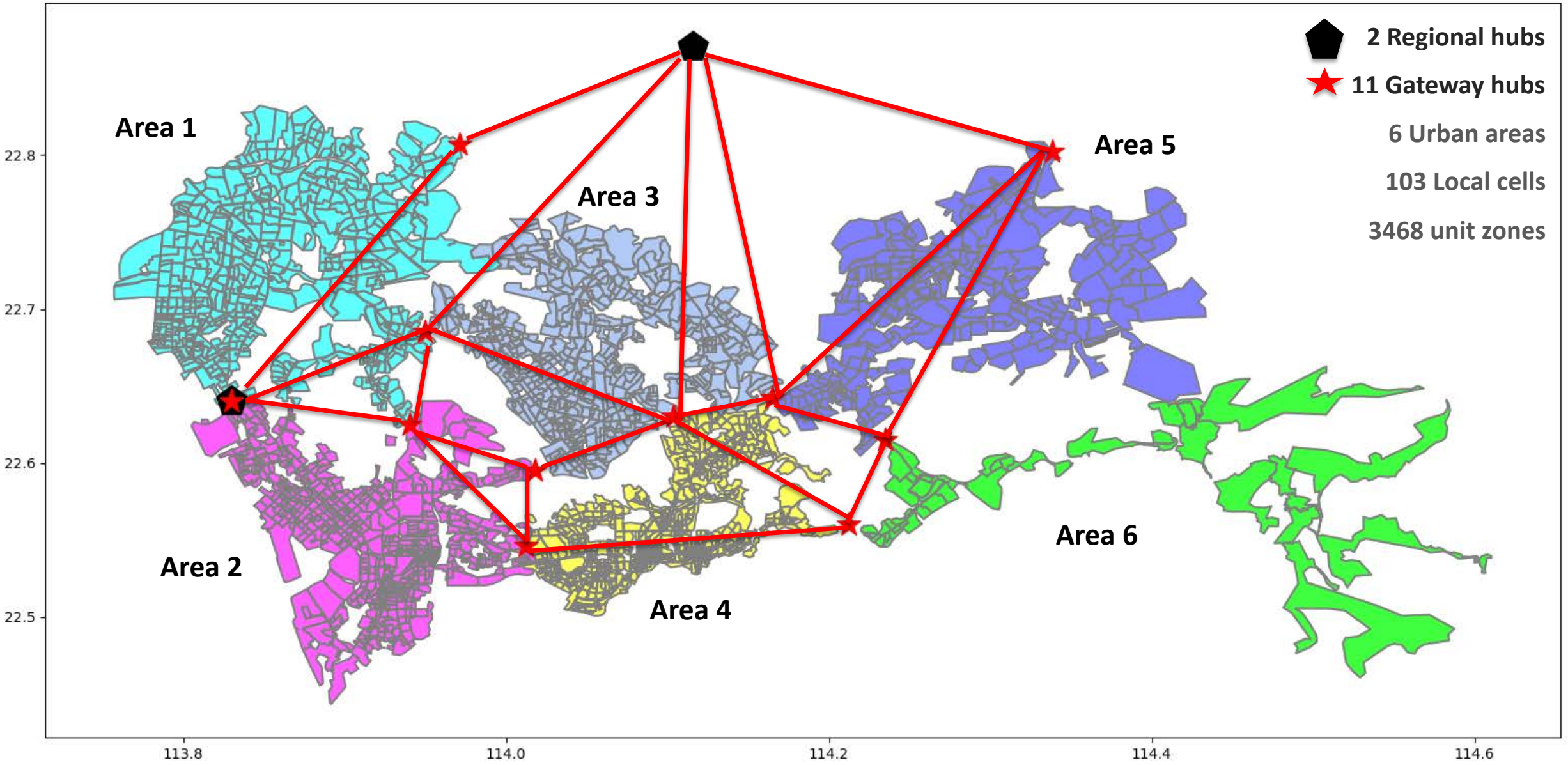




- **Dynamic Multi-Party Design and Management**
- **Account for Competition, Cooperation, Coopetition**
- **Aim for Efficiency, Fairness, Resilience, Sustainability**
- **Should be Simple to Leverage, Operate, and Evolve**

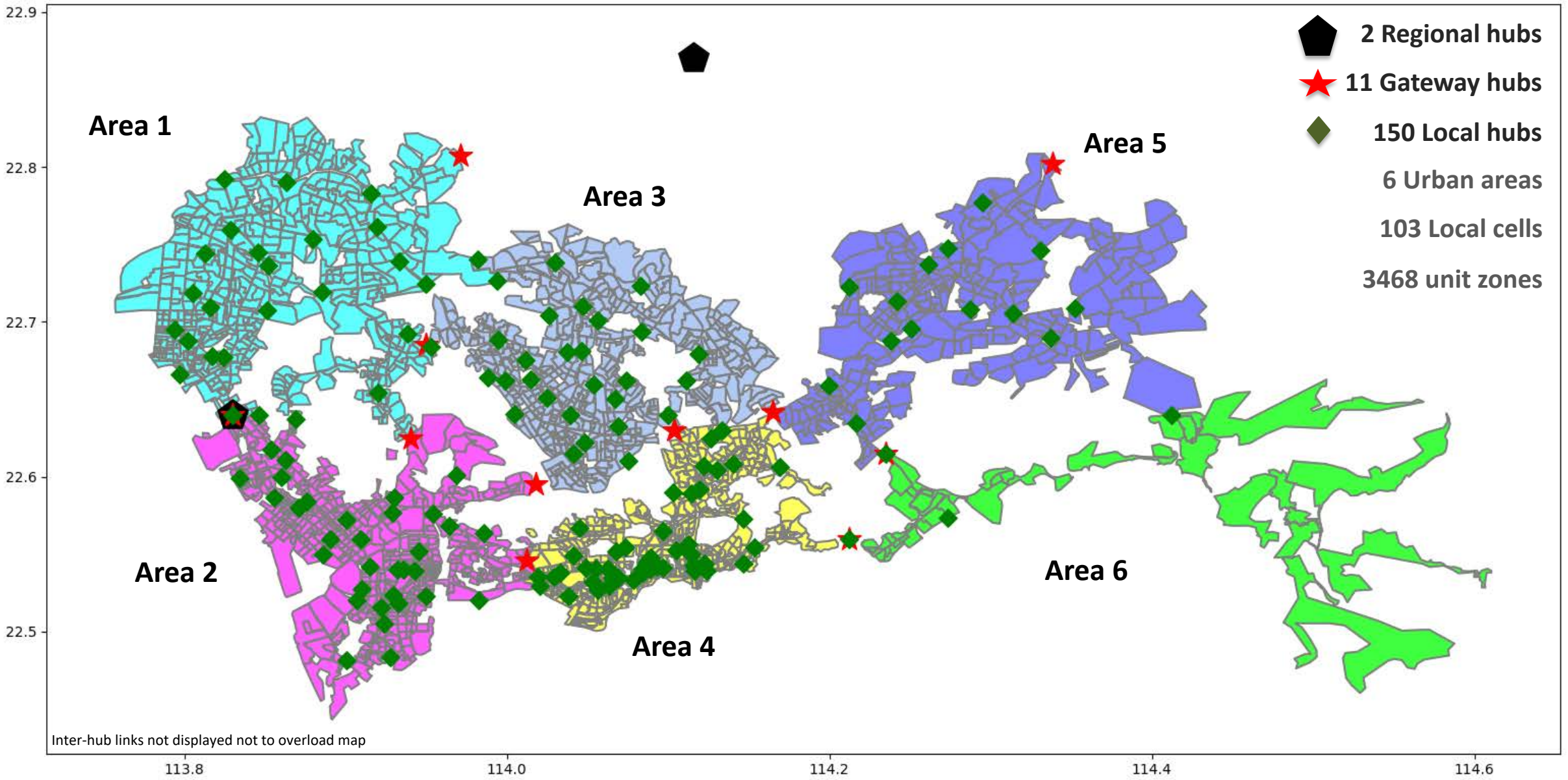
Adapted and extended from Montreuil B., S. Buckley, L. Faugere, K. Reem, S. Derhami, (2018). *Urban Parcel Logistic Hub and Network Design: The Impact of Modularity and Hyperconnectivity*, in **Progress in Material Handling Research, Vol. 15**, MHI, Charlotte, NC, USA, 8 p., 2018.

Urban Logistics Web: Gateway-Hub Network in Megacity



Space clustering and logistics web created by Ph.D. student Simon Kwon and Professor Benoit Montreuil for illustrative and benchmarking purposes: they are not meant to be prescriptive

Urban Logistics Web: Adding the Local-Hub Network



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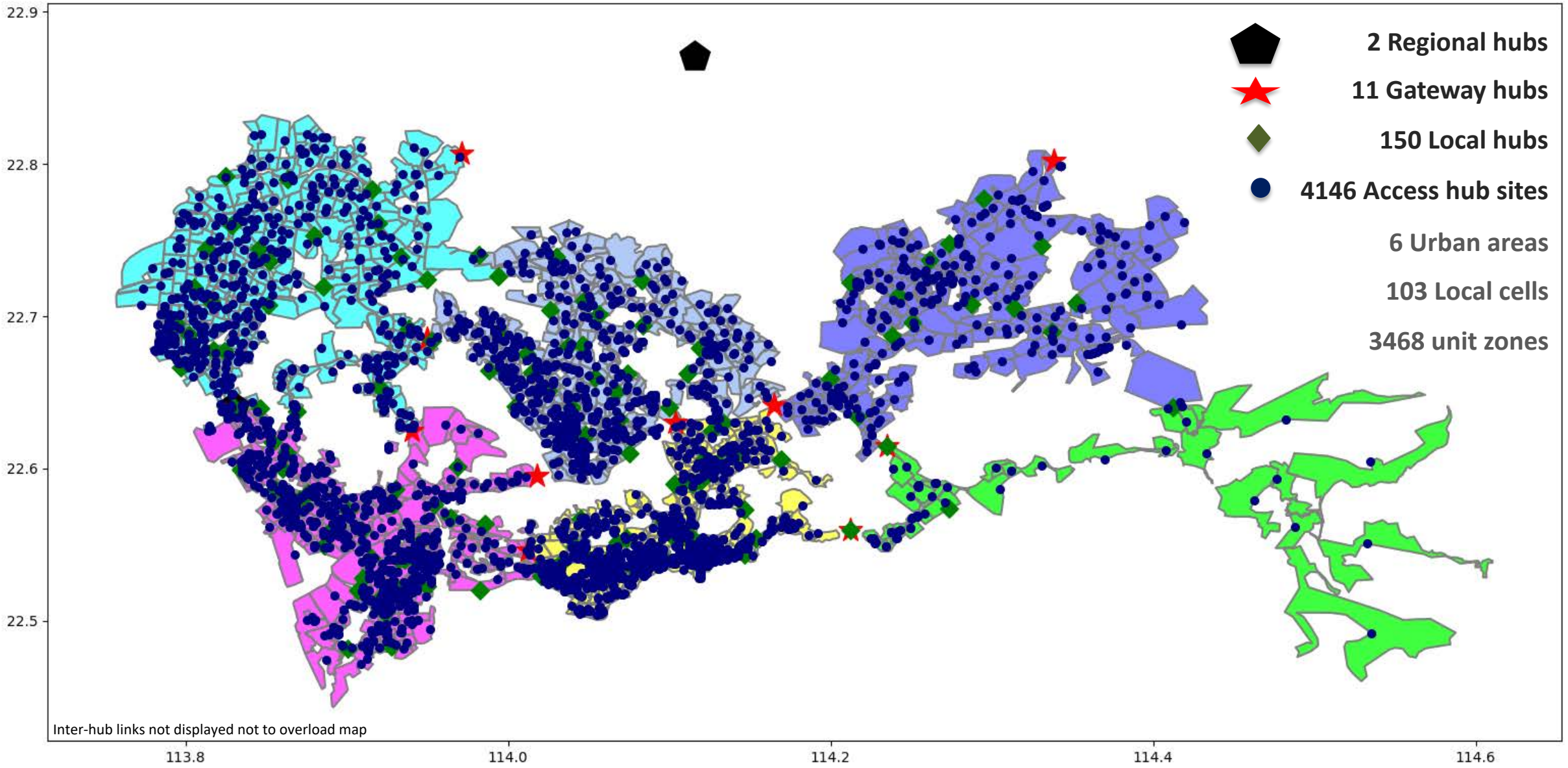
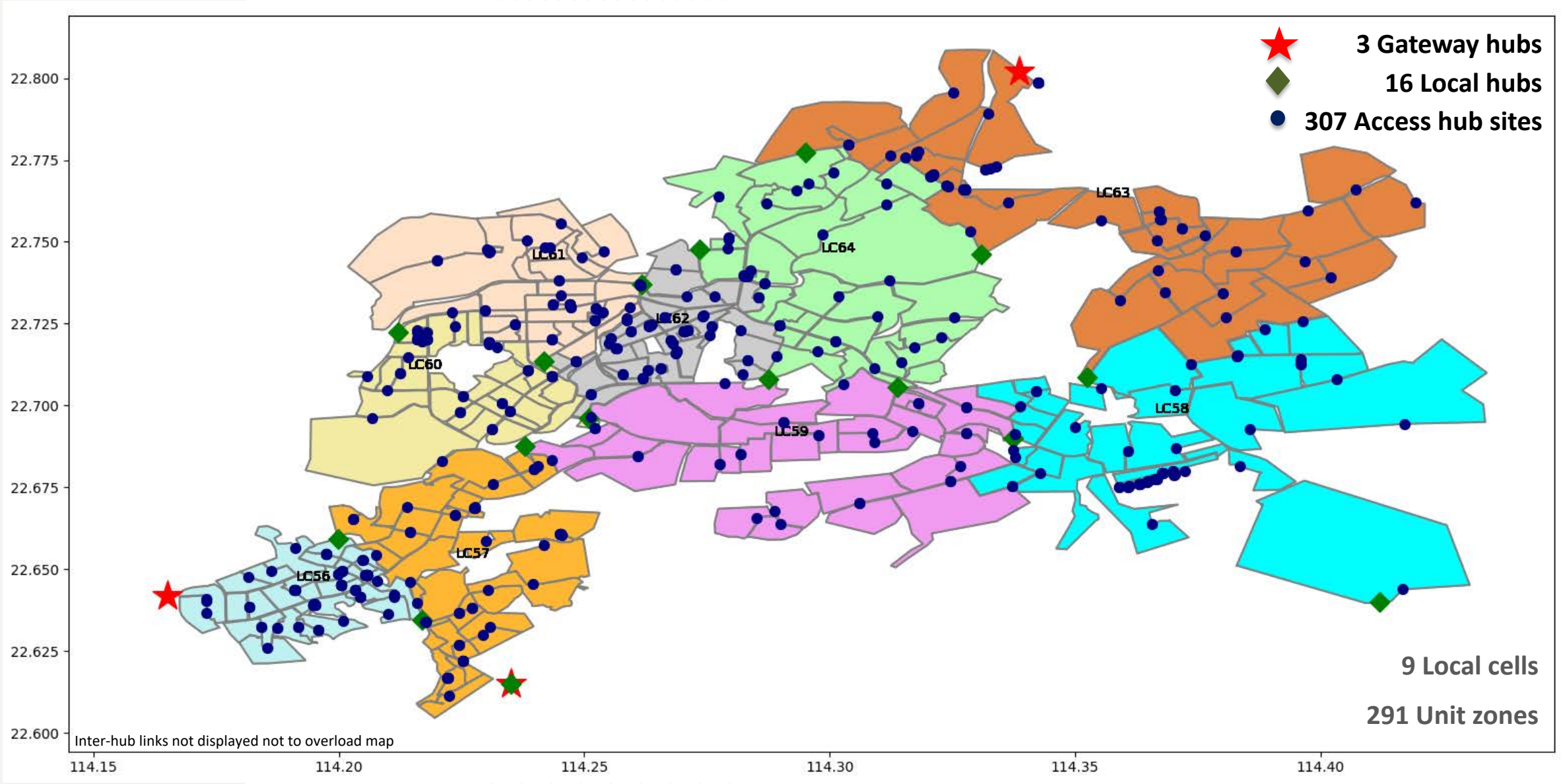
Urban Logistics Web: Adding the Access-Hub Network



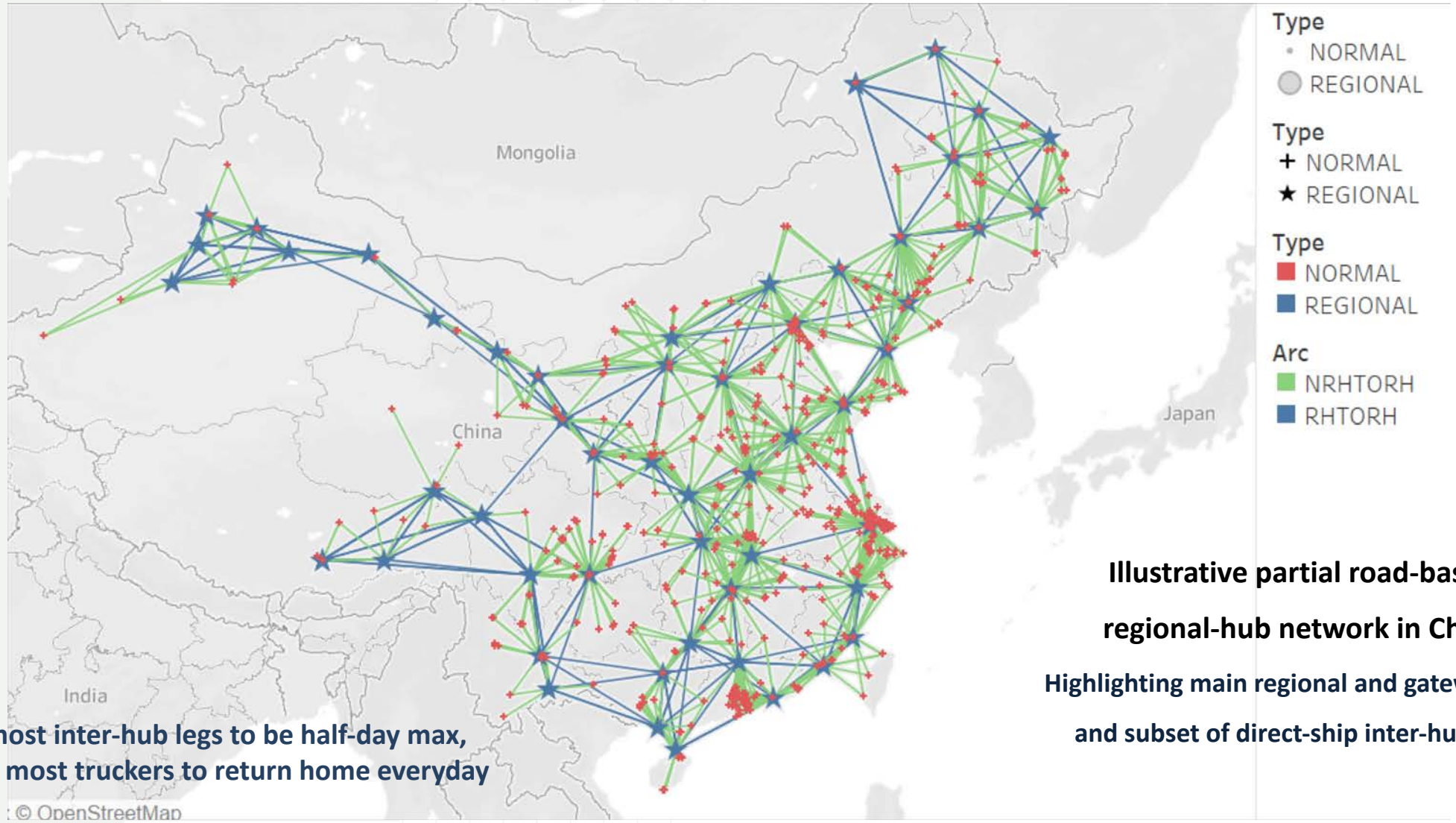
Space clustering and logistics web created by Ph.D. student Simon Kwon, MS student Praveen Mthukrishnan, and Professor Benoit Montreuil for illustrative and benchmarking purposes: they are not meant to be prescriptive

Urban Logistics Web: Focus on Networks in Urban Area 5



Space clustering and logistics web created by Ph.D. student Simon Kwon, MS student Praveen Mthukrishnan, and Professor Benoit Montreuil for illustrative and benchmarking purposes: they are not meant to be prescriptive

Hyperconnected Continental Logistics Infrastructure
Road-Based Regional-Hub Network



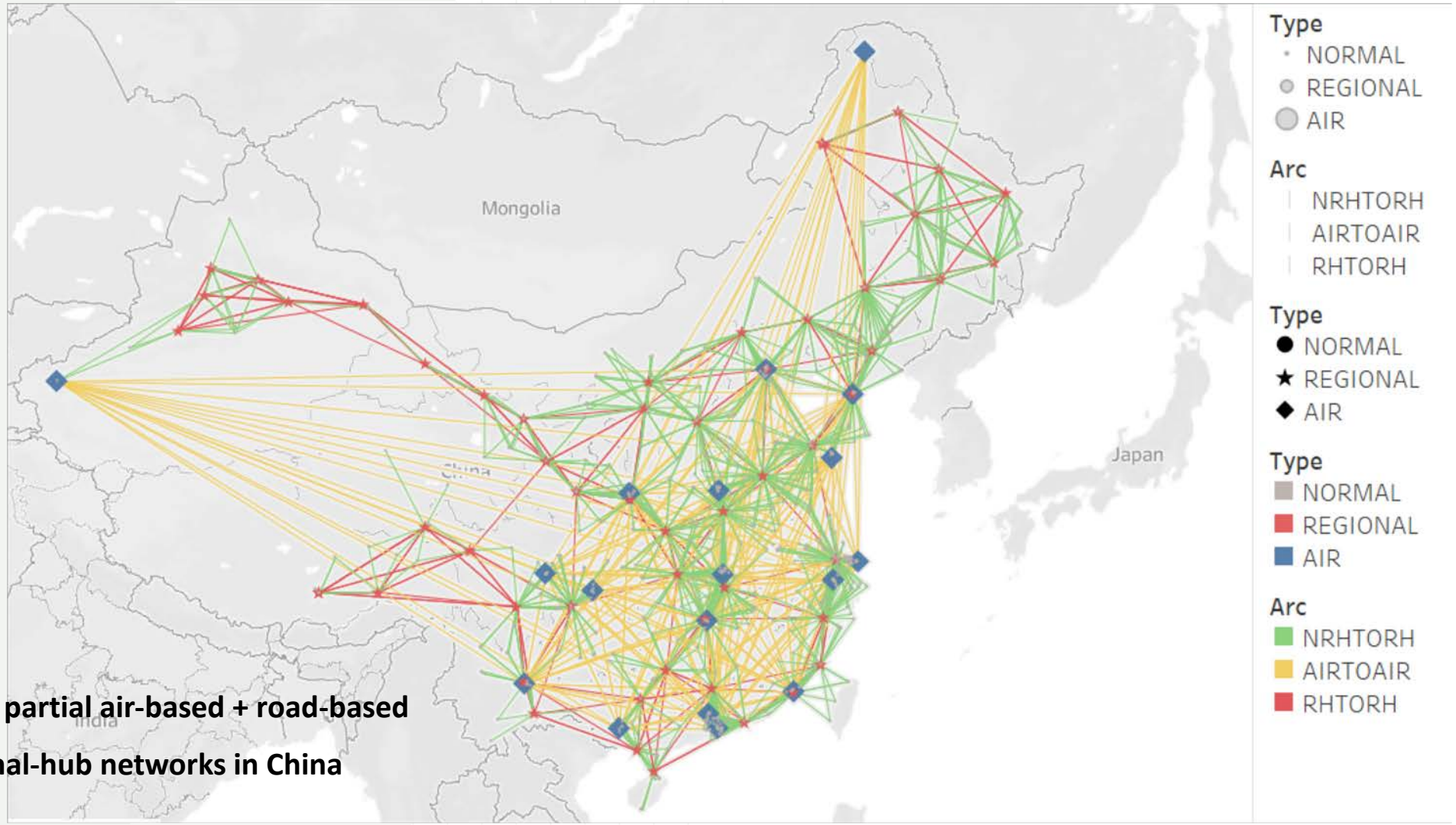
Illustrative partial road-based regional-hub network in China

Highlighting main regional and gateway hubs and subset of direct-ship inter-hub links

This design has most inter-hub legs to be half-day max, notably enabling most truckers to return home everyday

Inter-regional-hub logistics network created by Ph.D. student Onkar Kulkarni and Yaarit Cohen, and Professors Benoit Montreuil and Mathieu Dahan for illustrative and benchmarking purposes: it is not meant to be prescriptive

Hyperconnected Continental Logistics Infrastructure
Interconnected Air-Based & Road-Based Regional-Hub Networks



Illustrative partial air-based + road-based regional-hub networks in China

Inter-regional-hub logistics network created by Ph.D. student Onkar Kulkarni and Yaarit Cohen, and Professors Benoit Montreuil and Mathieu Dahan for illustrative and benchmarking purposes: it is not meant to be prescriptive

Hyperconnected Logistics Infrastructure
Embracing Modularity, Scalability, and Mobility of Facilities

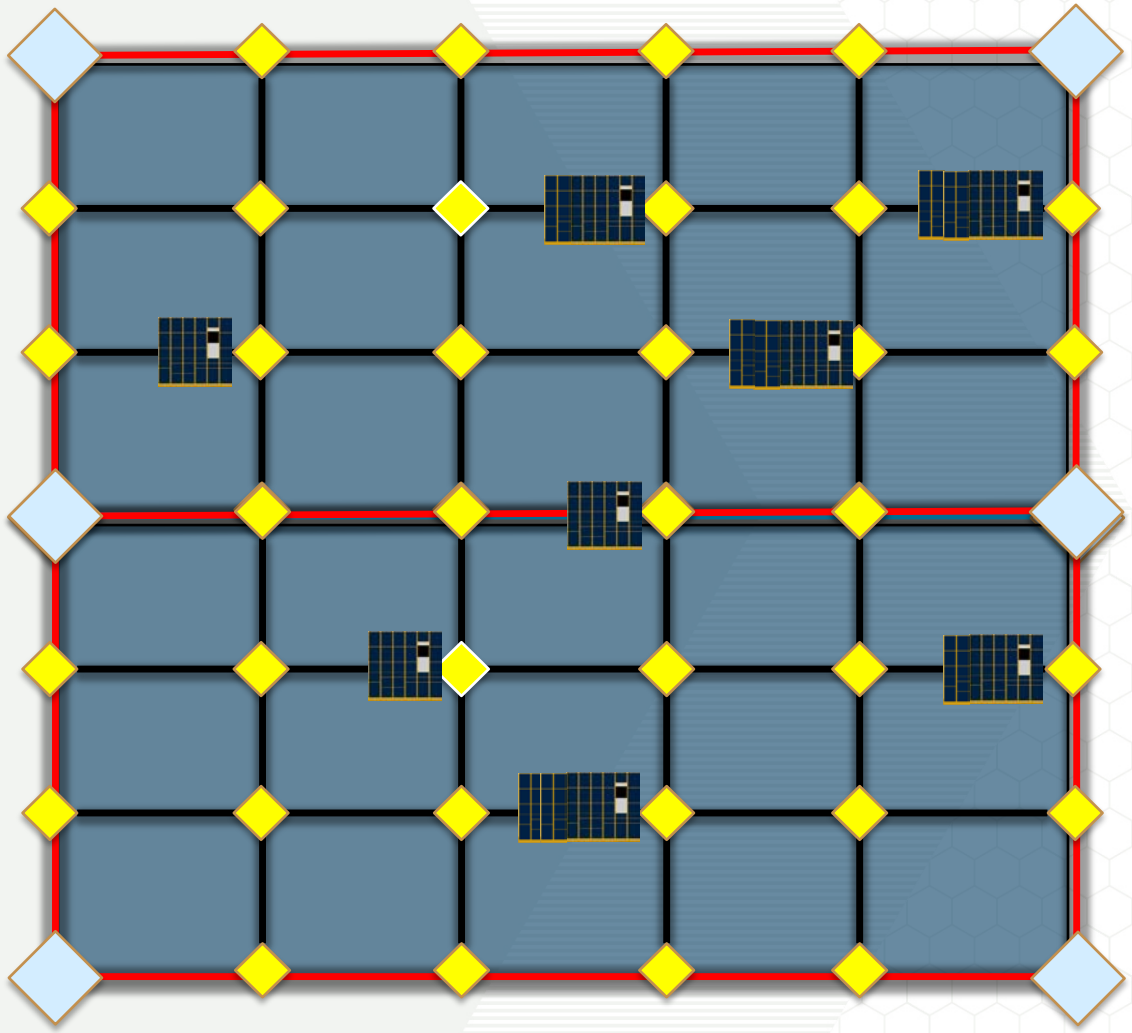
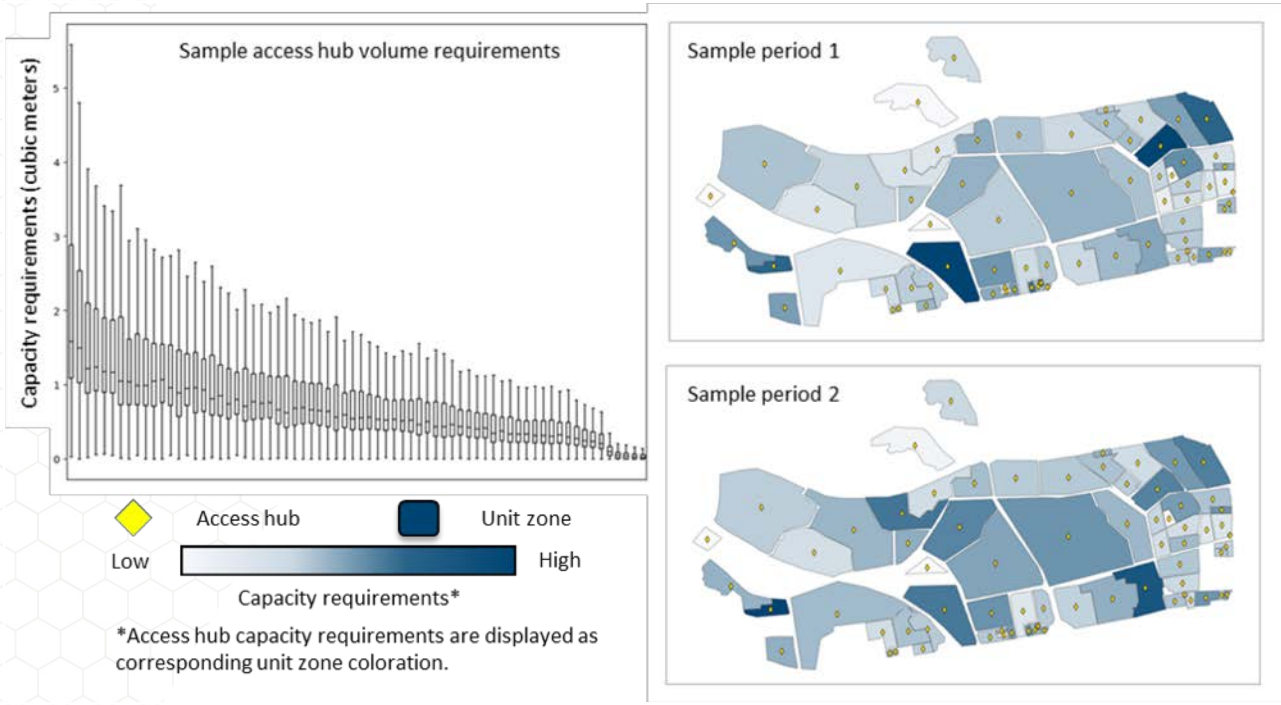


Illustration of periodic modular hub capacity relocation

Leveraging Modular Access Hubs



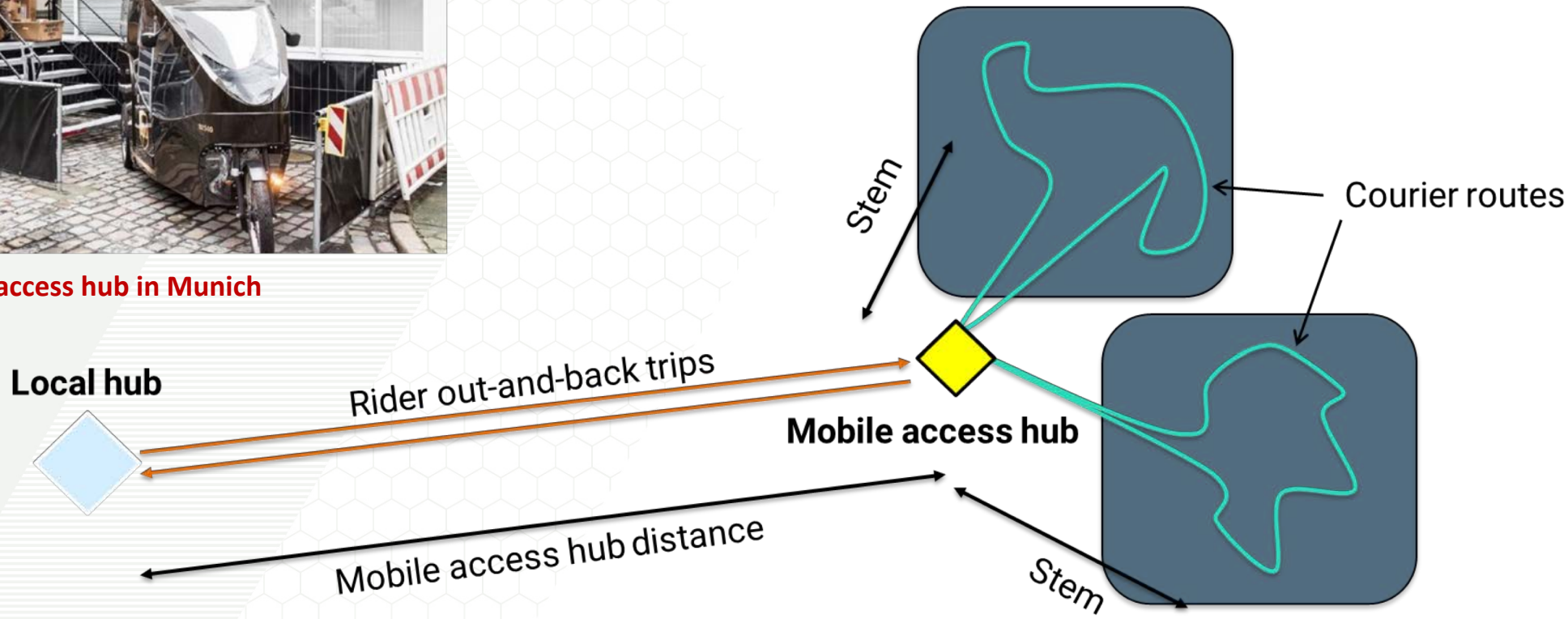
Sample demand dynamics in a local cell

L. Faugère, W. Klibi, C. White III, and B. Montreuil (2020). Dynamic Pooled Capacity Deployment for Urban Parcel Logistics, arXiv:2007.11270 [cs, math], Jul. 2020, arXiv:20-07.11270, 2020. under review for journal publication

Hyperconnected Logistics Infrastructure
Embracing Modularity, Scalability, and Mobility of Facilities

UPS's mobile access hub in Munich

Leveraging Mobile Access Hubs



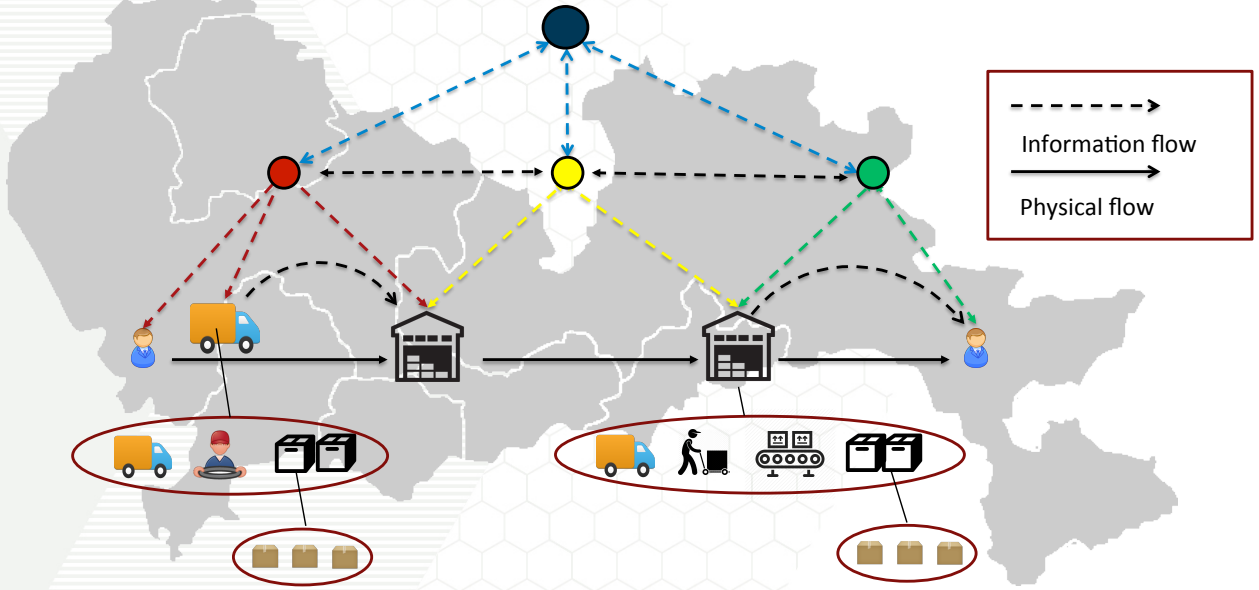
Faugère, L., White III, C., Montreuil, B. (2020). Mobile Access Hub Deployment for Urban Parcel Logistics. Sustainability, 12(17) 7213

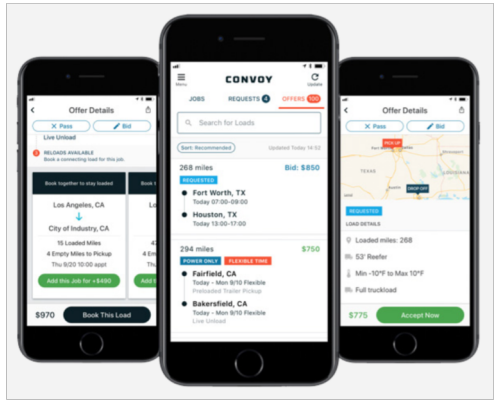
Hyperconnected Digital Logistics Infrastructure

Towards Cloud-Based Digital Supply Chain Interconnectivity Platforms

Seamless, Trustworthy, Ubiquitous Monitoring, Traceability & Transactions

Schematics provided by the Consumer Goods Forum
www.theconsumergoodsforum.com





Example: https://convoy.com/

Simple Links

Exploitation of industry-wide supply chain monitoring concepts from Consumer Forum Group

Internet-of-Things

Widespread exploitation of smart connected devices, and of sensor-actuator networks

BlockChain

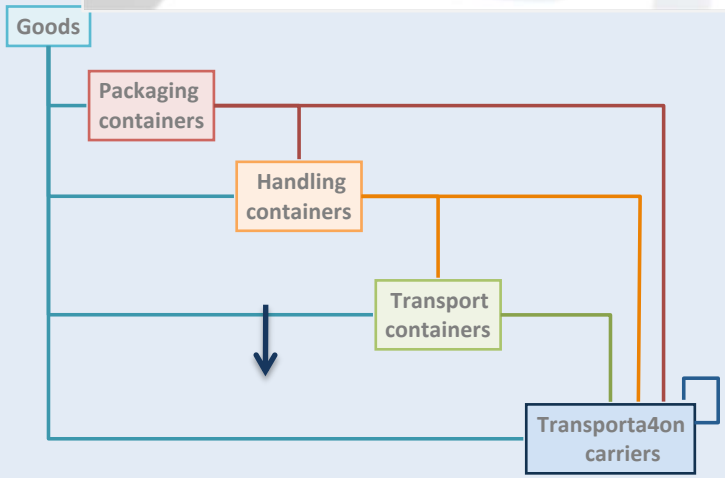
Exploitation of emerging distributed ledger technology for SC trust insuring platform

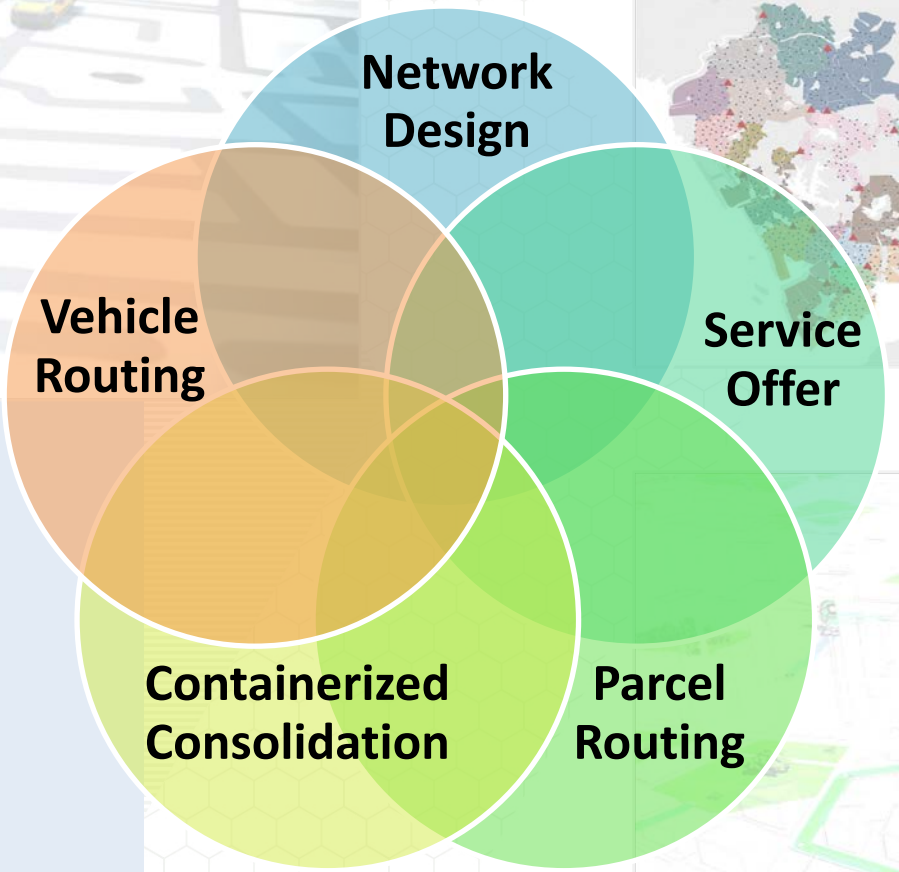
Marketplace

Match, orchestrate & optimize supply & demand for fast, seamless & fair contracts

Tranparency, tracking, traceability, smart contracts and distributed routing

Hyperconnected Digital Logistics Infrastructure
Supporting Live Multi-Party Protocols, Predictions & Decisions





Enabled by Analytics, AI, Data Science, Digital Twins, Heuristics, Machine Learning, Optimization, Simulation

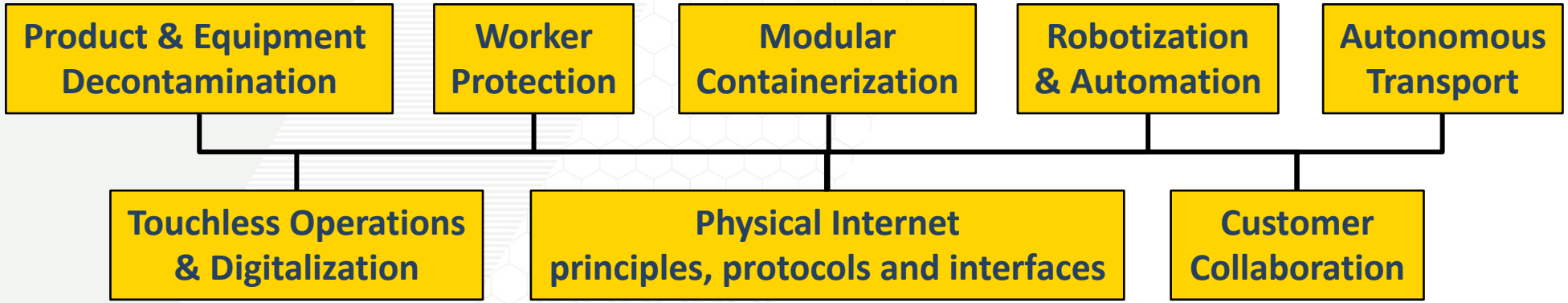
Hyperconnected Vector-Free Logistics Infrastructure

Logistics receives, unpacks, sorts, moves, stores, picks, packs, ships, transports, and delivers goods

At each step, people, equipment, and products can become vectors propagating pandemic viral diseases

Vector-Free Logistics

The overall multi-party logistics system in a large territory, and ultimately all around the world, is designed, engineered, implemented, operated and managed not to be an infection vector, protecting the workers, the customers, and the population from diseases, while not being encumbered into inefficiency, rigidity and unsustainability



Joint work with Professor Leon McGinnis

Conclusion

- The potential benefits are huge, notably in terms of capability, efficiency, equity, resilience, safety, security, and sustainability
- Leadership is needed in steering toward implementation at large scale
- Roadmap is needed, as ALICE PI Roadmap, focused on hyperconnected logistics infrastructure
- Starting in industries having to rethink their supply chain and logistics, notably toward post-Covid-19 New Normal
- Key challenge is the existing legacy and the competitive arena
- Governance is to be mandatory to align the early efforts of multiple parties, manage risks, and guide toward full-scale implementation

Thanks Xièxiè

Questions, comments, feedback, suggestions are most welcome!

Professor Benoit Montreuil

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