Design and Coordination of a Public Logistics Network

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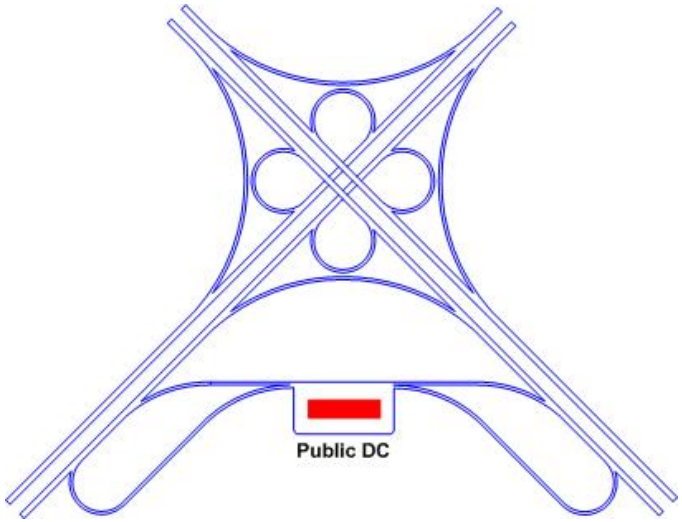
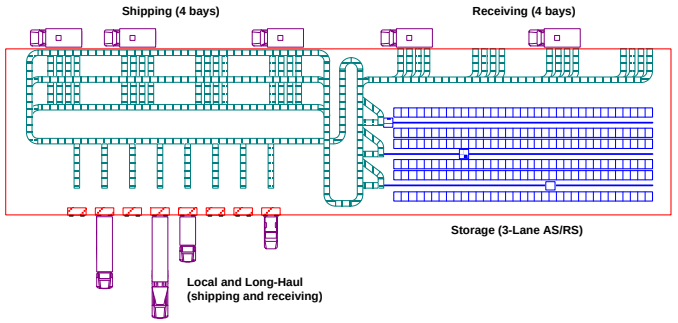
Public Logistics Networks

- Proposed as alternative to private logistics networks (like UPS) for ground transport of packages.
- **Local transport:** For example, package sent from retail store and then routed through sequence of public distribution centers (DCs) located throughout metropolitan area and then delivered to customer's home in a matter of hours.
- **Intercity transport:** DCs located at major highway interchanges to reduce loading/unloading time.



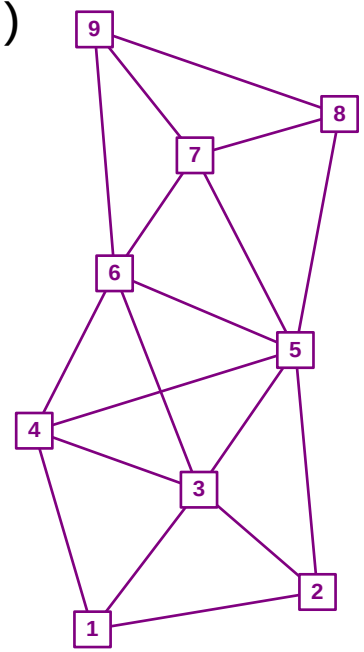


Public vs. Private Logistics Networks

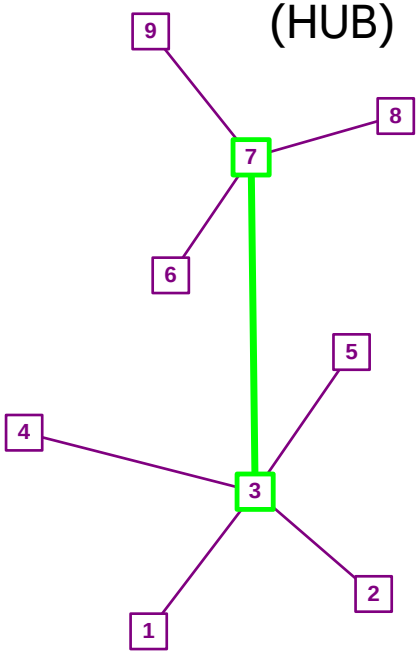
Public Network	Private Network
Each truck and DC can be operated by different firm	Single firm (e.g., UPS) handles package throughout its transport
Each truck and DC has access to potentially all of network's demand $\Rightarrow$ scale economies	Each truck and DC has access to only single firm's portion of demand
Decentralized control	Centralized control
Public DCs and open coordination protocols provide low barrier to entry	Private hubs/terminals result in high barrier to entry for parcel and LTL transport

Comparison of Network Alternatives

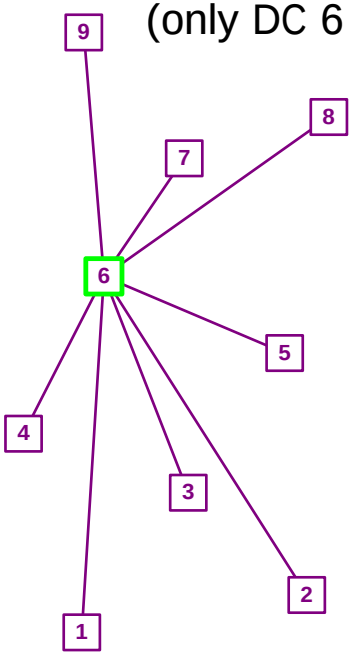
Public Logistics Network (PLN)



Hub-and-Spoke (HUB)

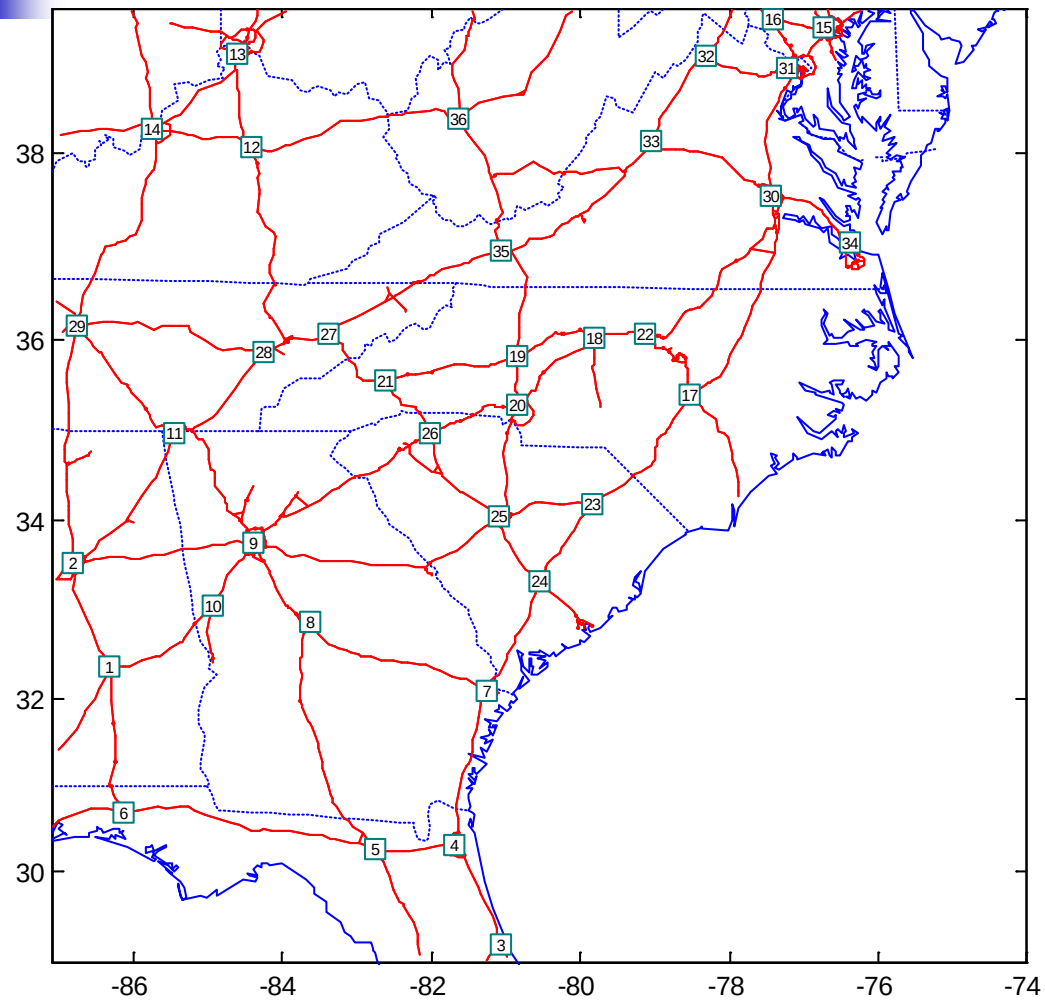


Point-to-Point (P2P) (only DC 6 shown)



When preferred:	PLN	HUB	P2P
Loading/unloading time	Low	High	High
Transport demand	High	Low	High

Hypothetical Network



- Covers portion of southeastern US
- 36 public DCs
- DCs connected via interstate highways
- Public DCs:
  - Interstate DCs (shown)
  - Local DCs (not shown)

Current Research Issues

I. Design of a Public Logistics Network
II. Design of a Public DC
III. Network Coordination via Bidding

I. Design of a Public Logistics Network

- Two design problems:
  1. Given candidate set of DC locations, determine number of DCs and their location
     - Continental U.S.
     - Each metropolitan area
  2. Given number and location of DCs, determine arcs/lanes in network
     - Subroutine in first design problem
     - 36-DC hypothetical network used
     - Provides insight into economics of PLN and DC design issues
- To implement PLN, neither problem needs to be “solved”
  - Coordination protocols allow network operation to adapt
  - Designs used just to predict performance
  - DCs added incrementally in response to market conditions

Average Transport Time

- Performance criterion to compare designs:

$$Average\ Transport\ Time = \sum_{i=1}^{36}\sum_{j=1}^{36} w_{ij}\, t_{ij}\ ,$$

where, w_{ij} = percentage of total demand from DC i to DC j

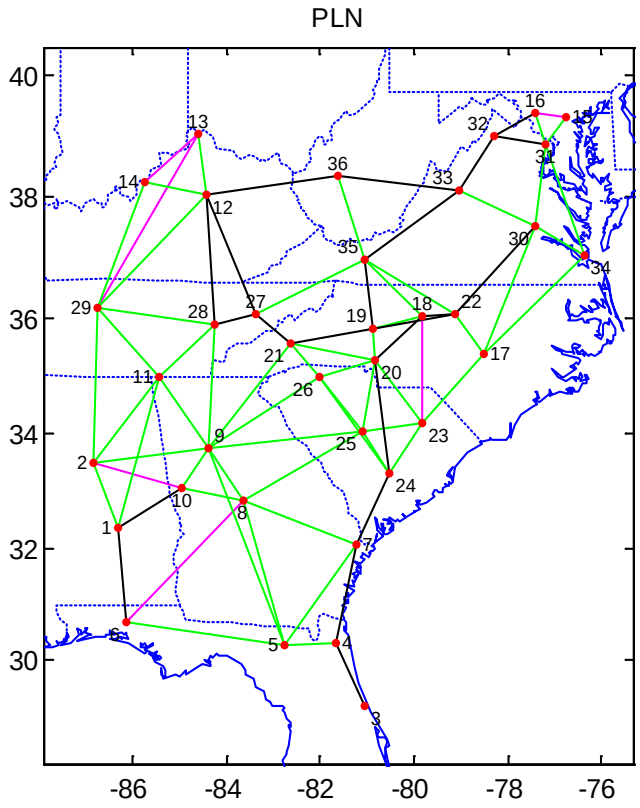
t_{ij} = Travel Time + L/U Time + Wait-for-Truck Time

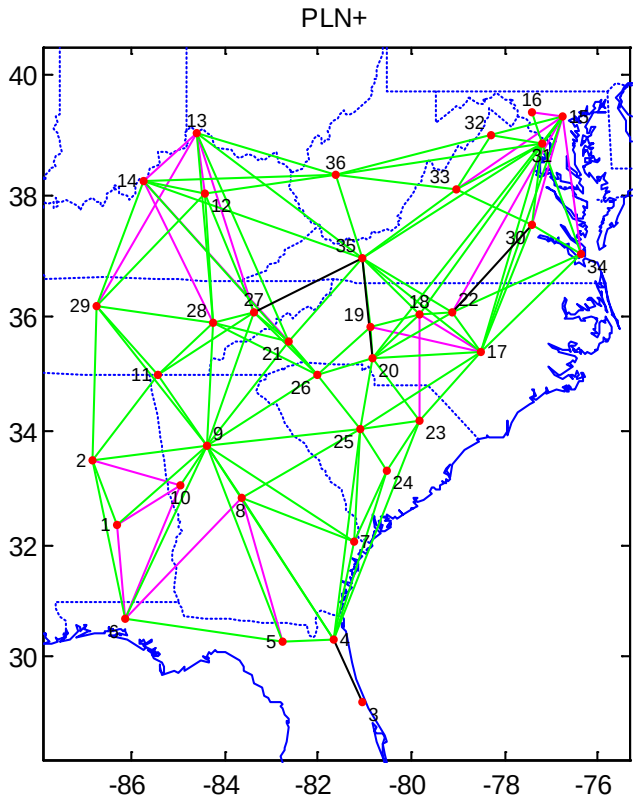
- Proximity factor used to relate demand to distance
- Wait-for-Truck Time estimated by:
  1. Summing total demand along each arc
  2. Dividing by average truck load (80% of its maximum capacity) to get number of truck trips
  3. Using half of headway (average time between trips) as expected waiting time estimate

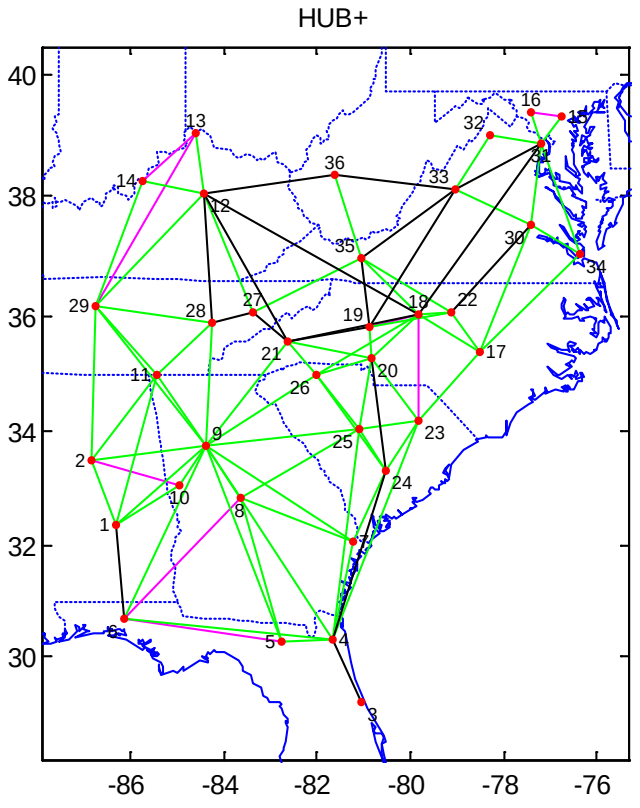
Example:

US SE: Half Headway:	Value
TrSpeed:	50.00
LdFac:	0.80
Hr:	24.00
TrCap:	2,000.00

Iter:	tLU	Prox	Pkg		HUB	PLN	PLN+	PLN-	P2P	HUB+	LB
1:	8	6	32	1	4.7342	3.6694	3.6787	3.6676	4.7742	-3.6593	3.3096



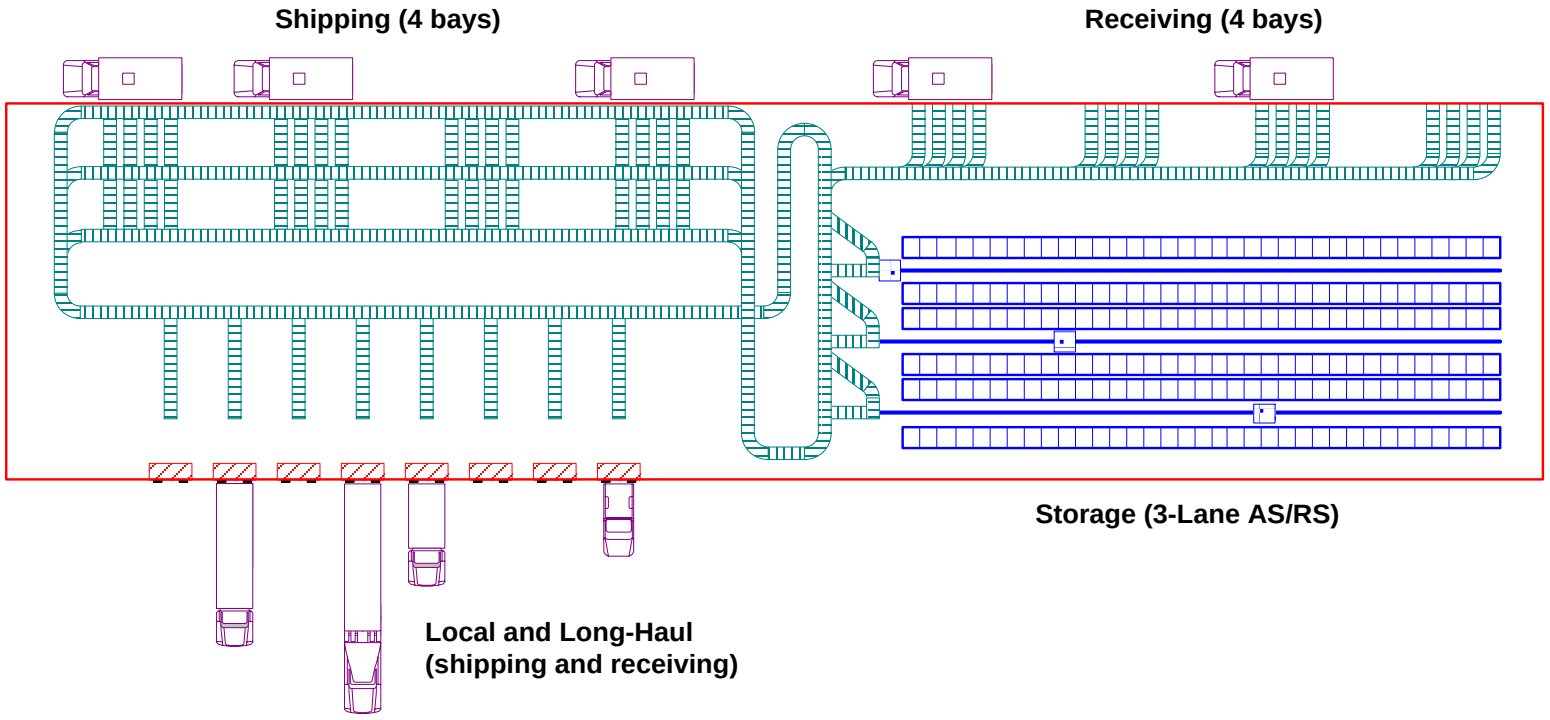




II. Design of a Public DC

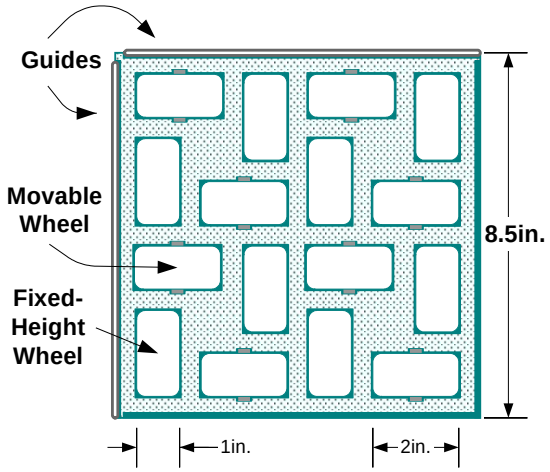
- Main requirements:
  1. Fast, fully automated loading/unloading
  2. Storage of different size packages
  3. Packages can be redirected any time prior to loading
  4. Low cost to build small DC, allowing many DCs to cover a single metropolitan area
  5. Small exterior footprint to allow locating in urban areas
- Traditional material handling technologies are not adequate with respect to all above requirements

Traditional DC Design

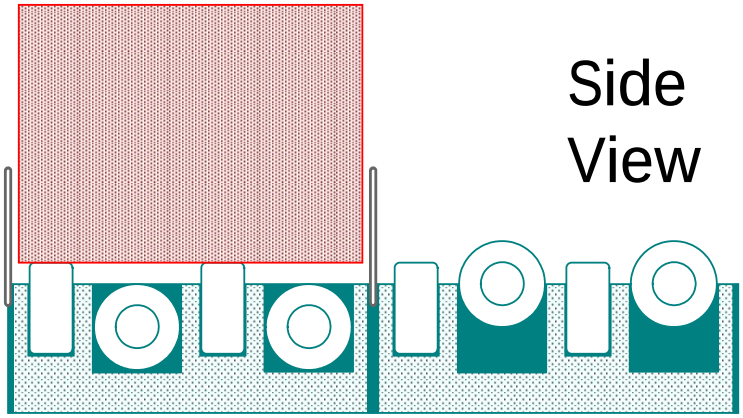


- Conveyors for all transport
- AS/RS for storage

Material Handling Module



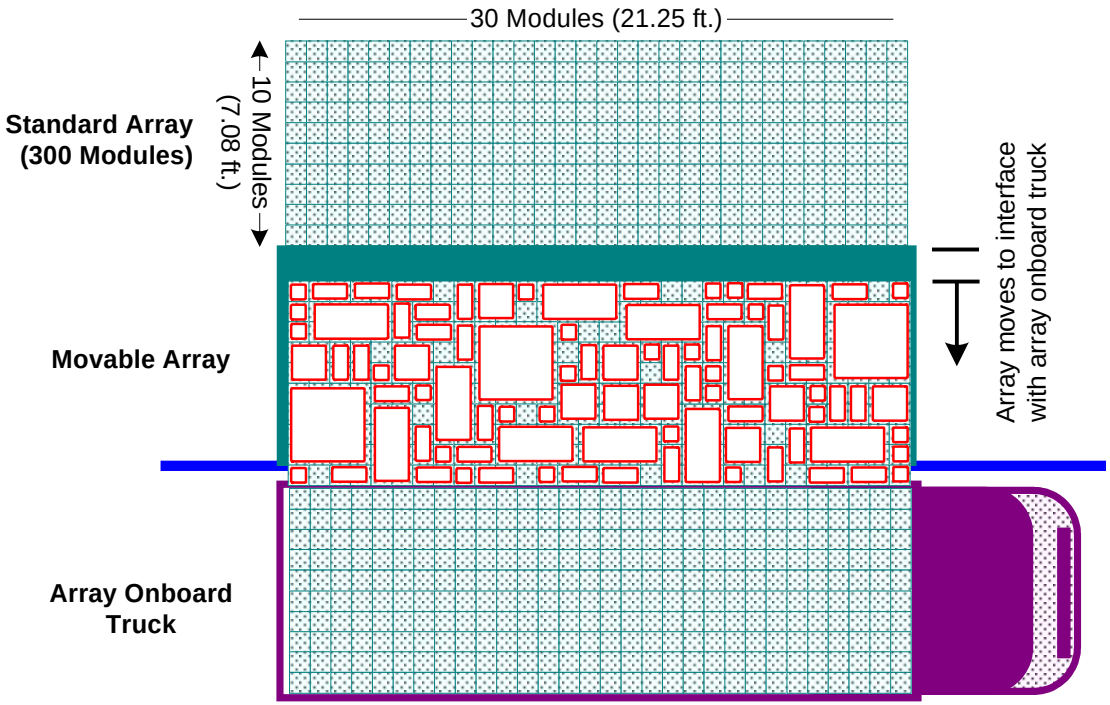
Top View



Side View

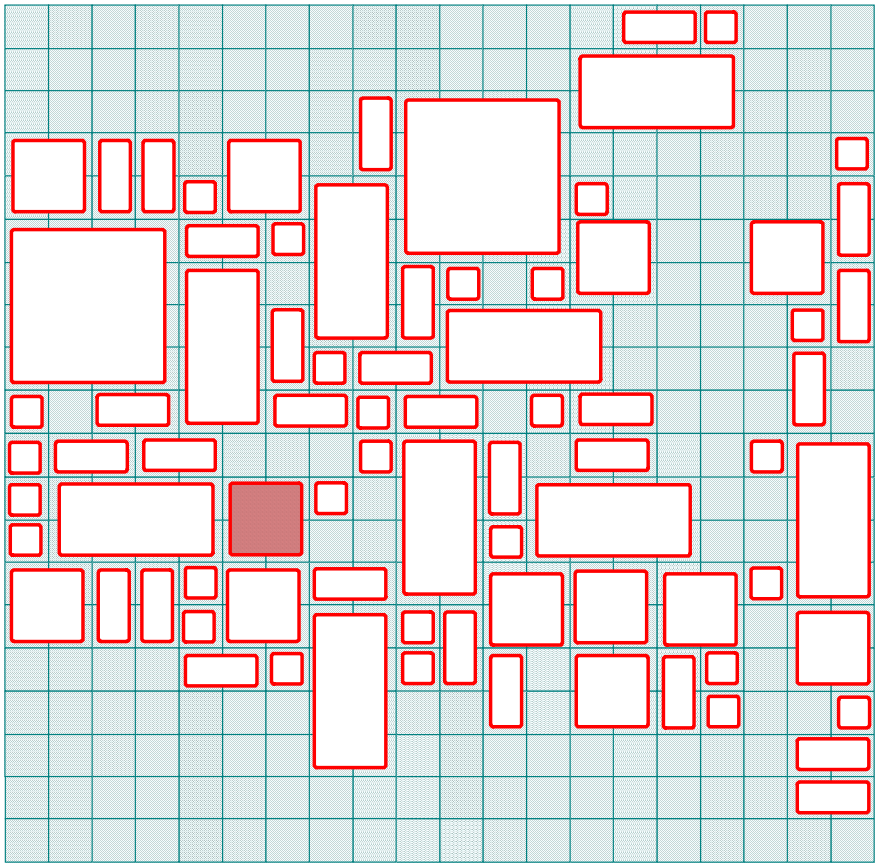
- Standardized 8.5-inch square module
- All material handling performed using arrays of modules
- Loads can occupy multiple modules
- Pop-up wheels used to translate load and make series of 90° turns
- Guides on module raised to direct load

Truck Loading and Unloading



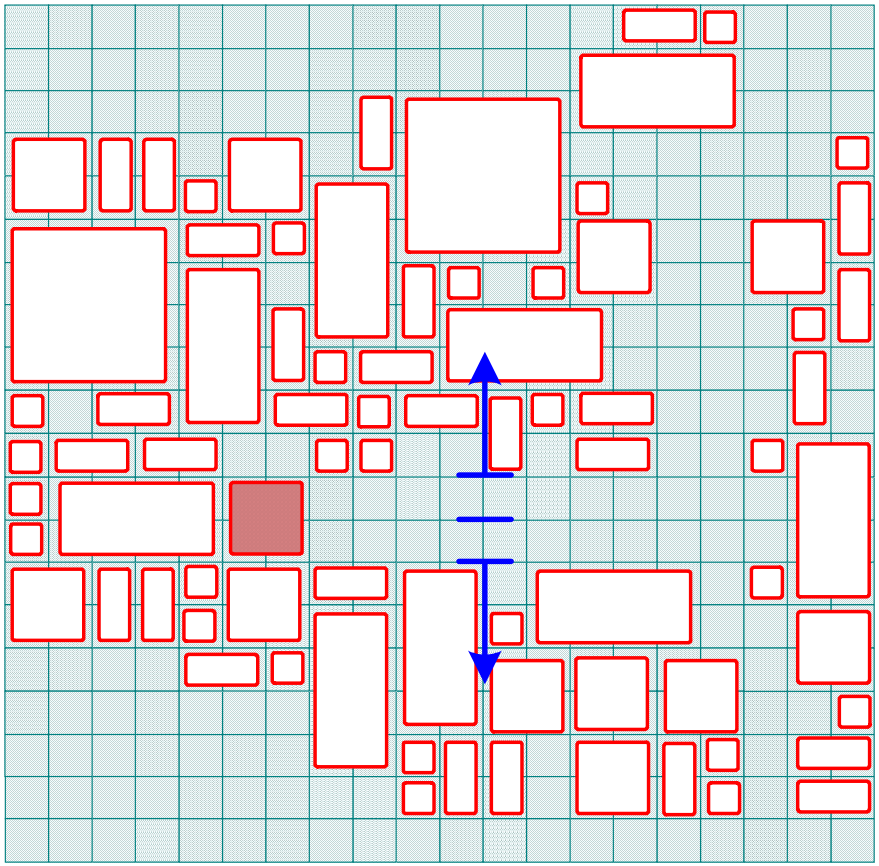
- Fully automated loading and unloading
- Truck use same type array used inside DC
- Movable array used to interface between DC and truck

Storage and Retrieval



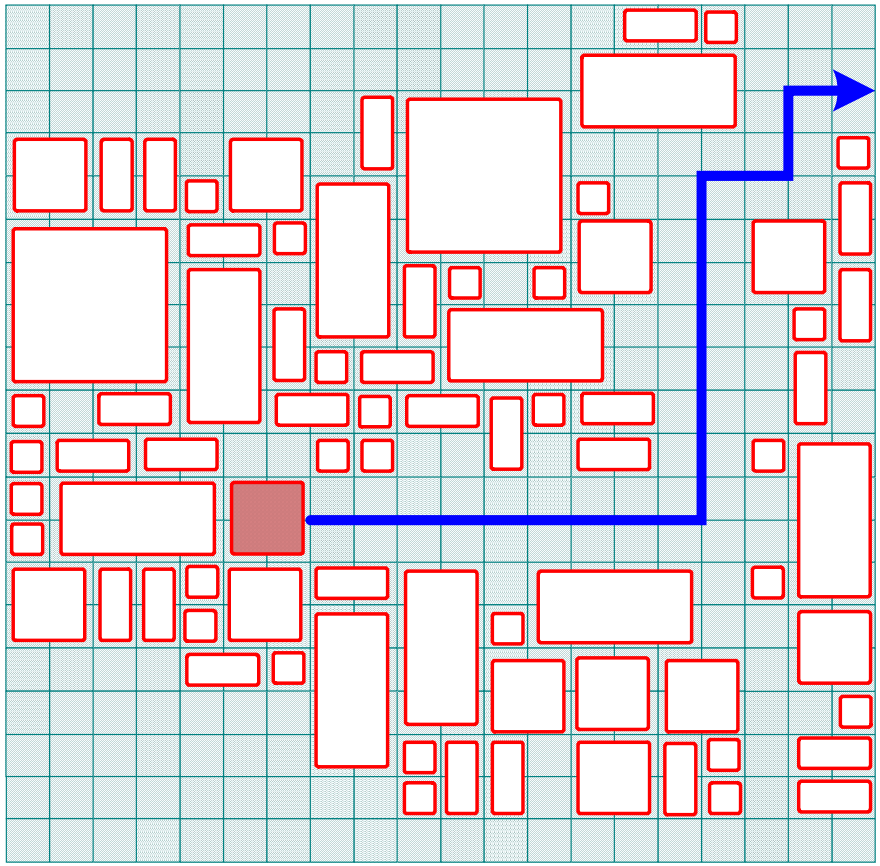
- Multiple loads can be densely stored on arrays of modules
- To retrieve shaded load:

Storage and Retrieval



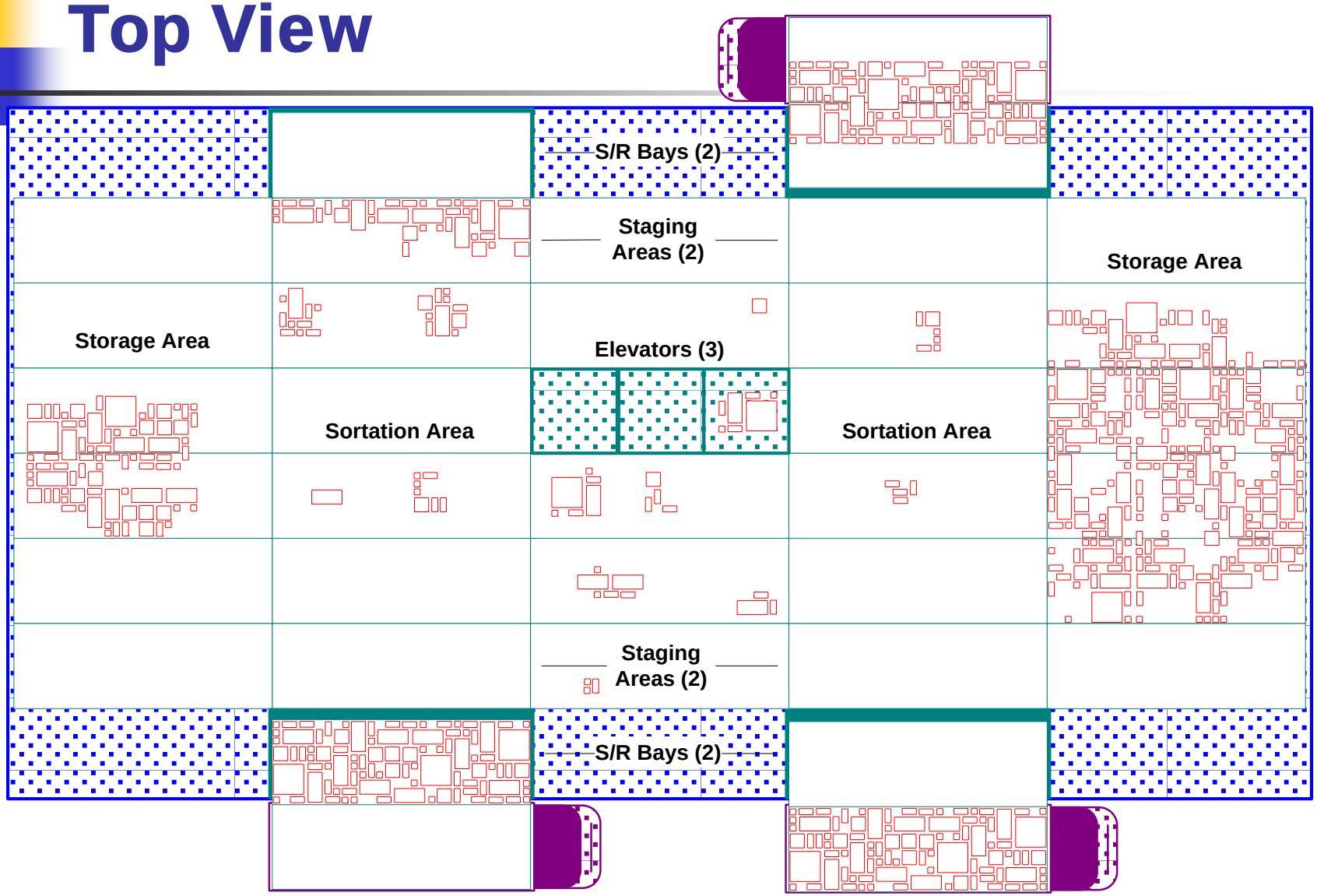
- Multiple loads can be densely stored on arrays of modules
- To retrieve shaded load:
  - Other loads move to clear path

Storage and Retrieval



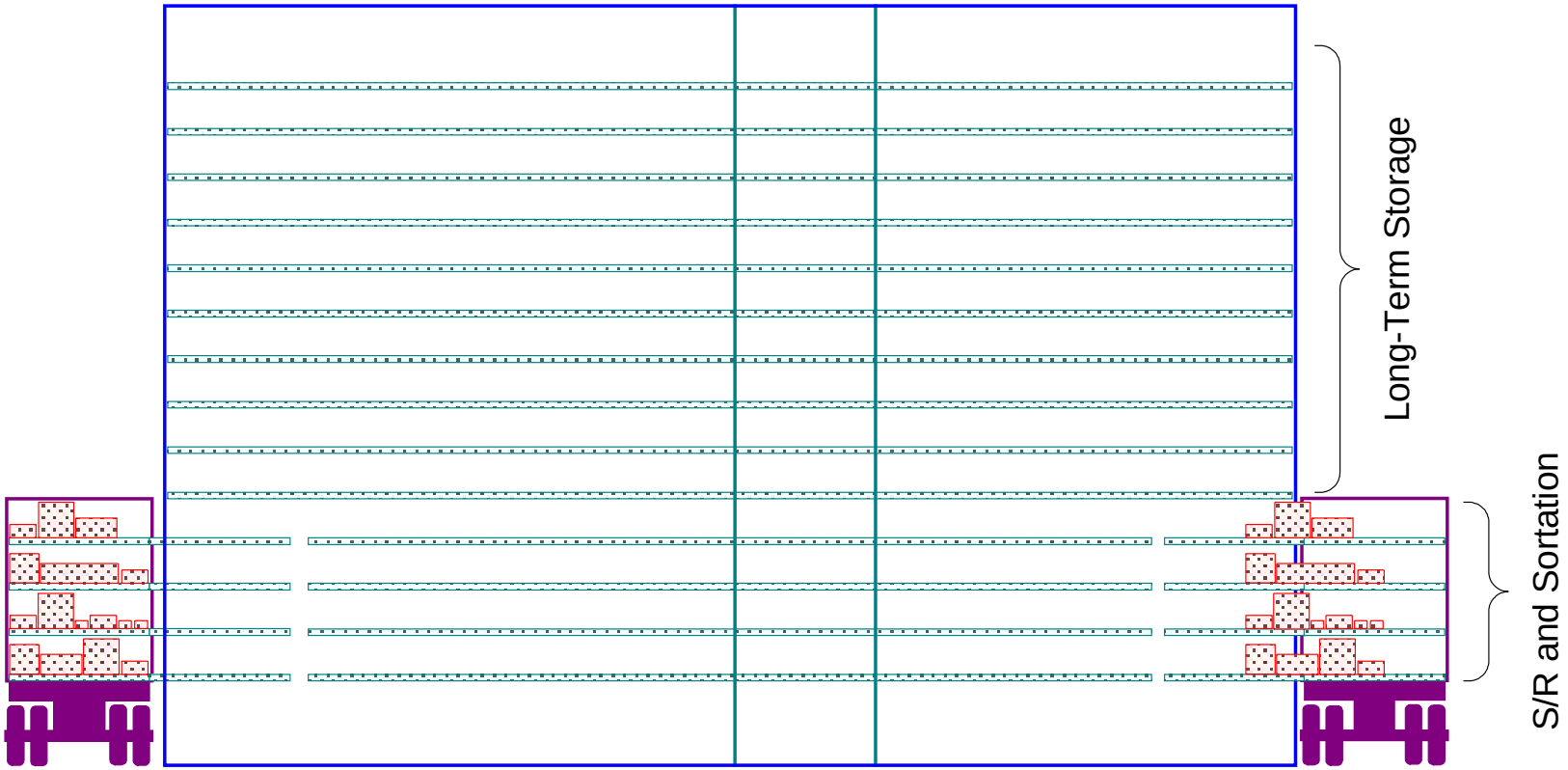
- Multiple loads can be densely stored on arrays of modules
- To retrieve shaded load:
  - Other loads move to clear path
  - Load makes series of 90° turns as it is transported

Public DC: Top View

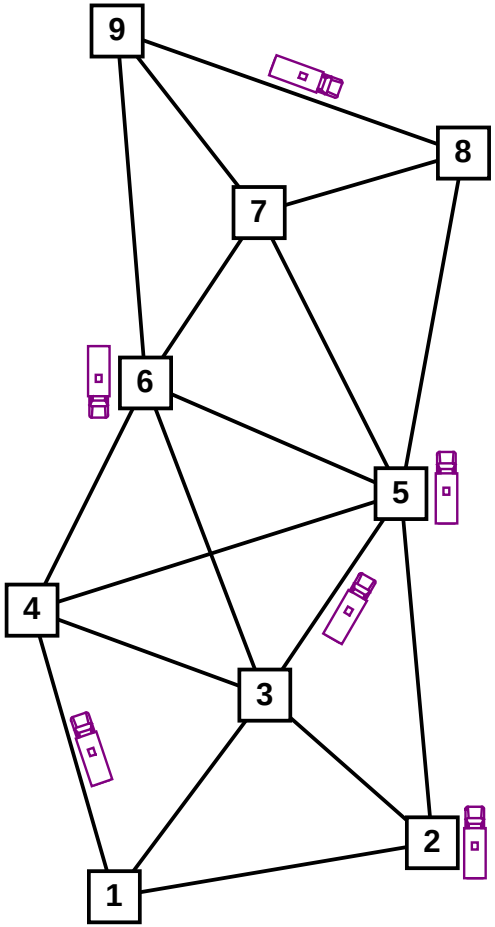


Public DC: Side View

- 4 levels for sortation and truck loading
- 10 levels for long-term storage

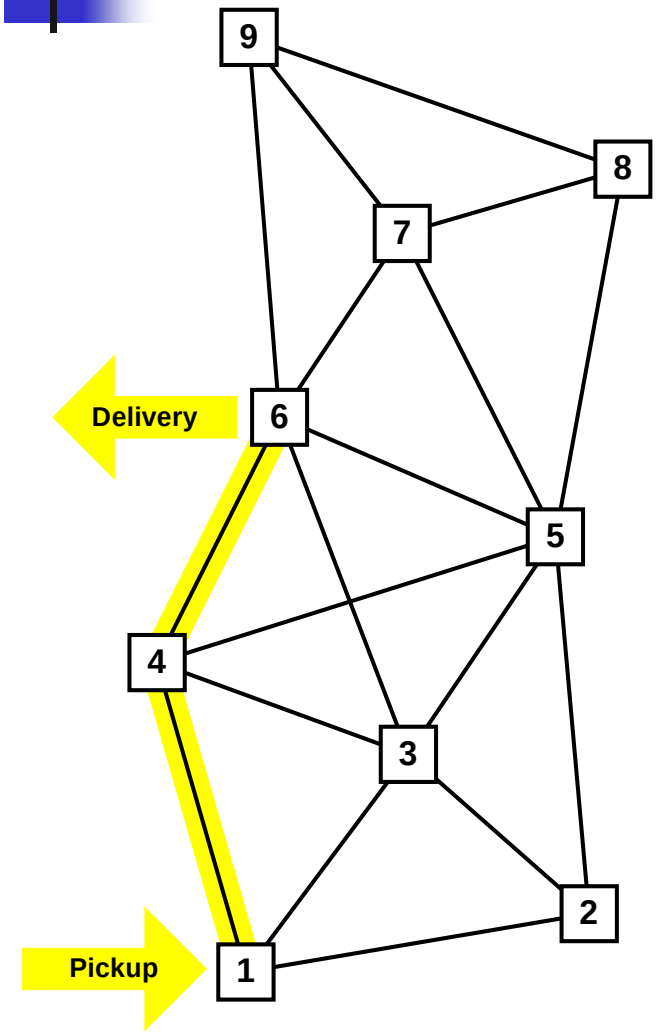


III. Network Coordination via Bidding



- Entities in network are DCs, trucks, and packages
- Since separate firms own each DC and truck, coordination of package transport is more difficult than in a private network
- Goal for Coordination Mechanism:
  - Make it possible for packages to maximize their value from transport, and trucks their profit
- Solution:
  - Packages bid for services of the trucks used for their transport
  - Packages pay each DC for time spent at DC and any other services

Transport of a Single Package

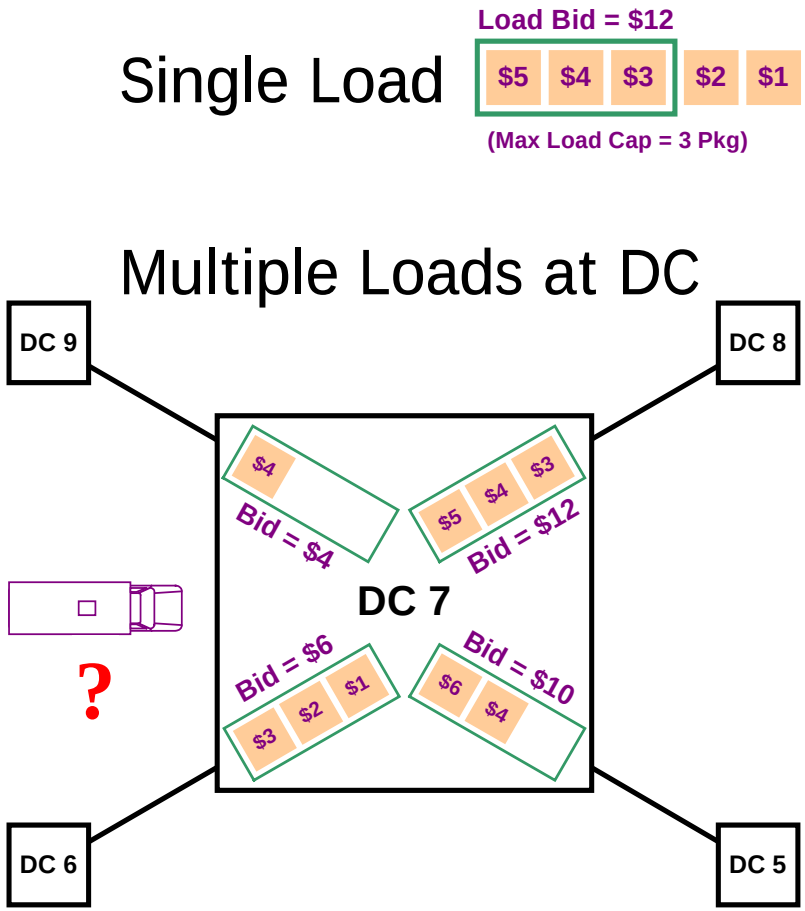


- *Total Time = L/U + DC Wait + Transit*
- Since DC Wait time is unknown, total transport time also unknown

  ⇒ Credit/debit can occur at delivery

	Activity	Time (min)	Credit	Bid	Cost
1	Pickup				
2	Unload	10	$3.00		$0.02
3	Wait at DC1	30	2.98		0.06
4	Load	10	2.92		0.02
5	Linehaul to DC4	60	2.90	$1.50	1.50
6	Unload	10	1.40		0.02
7	Wait at DC4	55	1.38		0.18
8	Load	10	1.20		0.02
9	Linehaul to DC6	60	1.18	$1.00	1.00
10	Unload	10	0.18		0.02
11	Delivery				
		255 4.25 hr	$0.16		$2.84

Package Bids

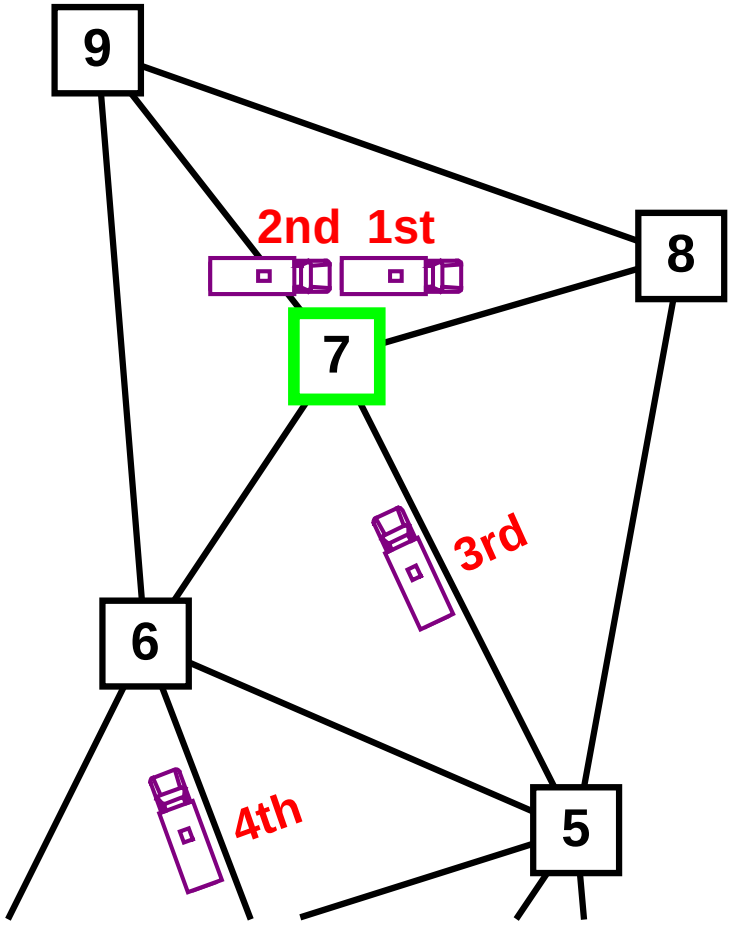


- *Load bid* is sum of package bids in load
- Packages compete on two levels:
  - Packages compete with each other to join a load
  - Packages in a load compete with other loads to be selected by a truck for transport

Truck Protocol

- Determines which truck is used to transport what load at what DC
- Goal for truck operation:
  - Try to match the load that values transport the highest with the truck that can provide that transport service at the least cost
- Protocol:
  1. **Priority for Accepting Loads:** Opportunity to accept or reject load based on truck's arrival time at DC
  2. **Reneging:** After reneging, truck cannot again accept same load until all other trucks have rejected it

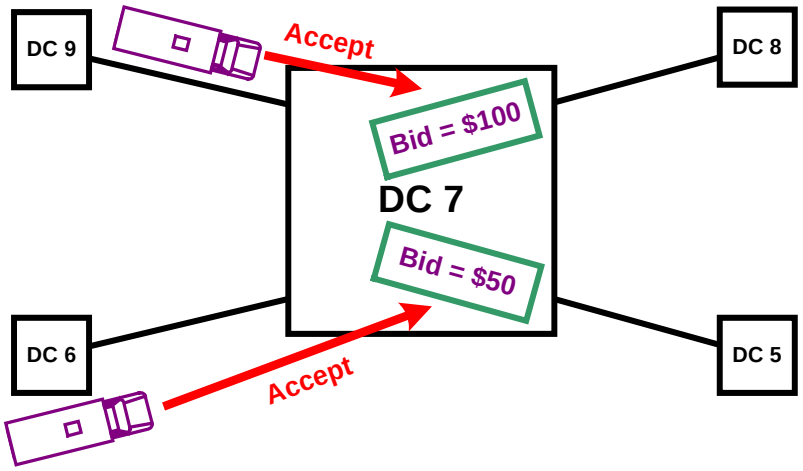
1. Priority for Accepting Loads



- Opportunity to accept or reject load based on truck's arrival time at DC
- Truck's portion of load bid fixed after acceptance
- If all trucks reject load, then it's posted at DC and available for any truck to accept

Load at DC 7

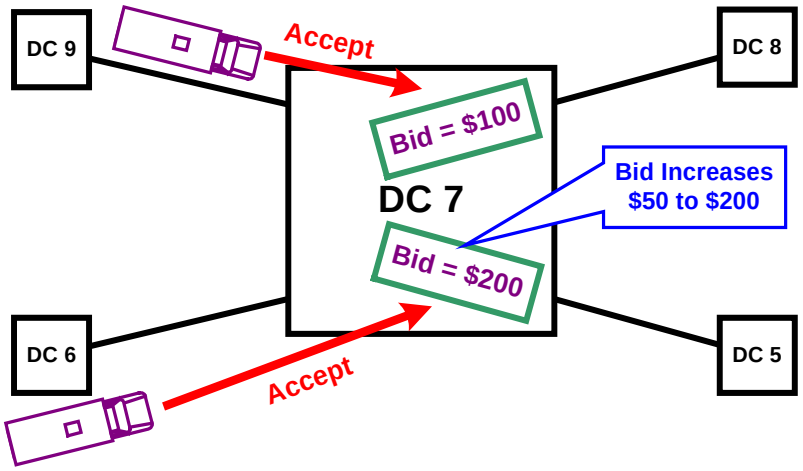
2. Reneging



- After reneging, truck cannot again accept same load until all other trucks have rejected it

Near and far trucks accept high and low bids, resp.

2. Reneging

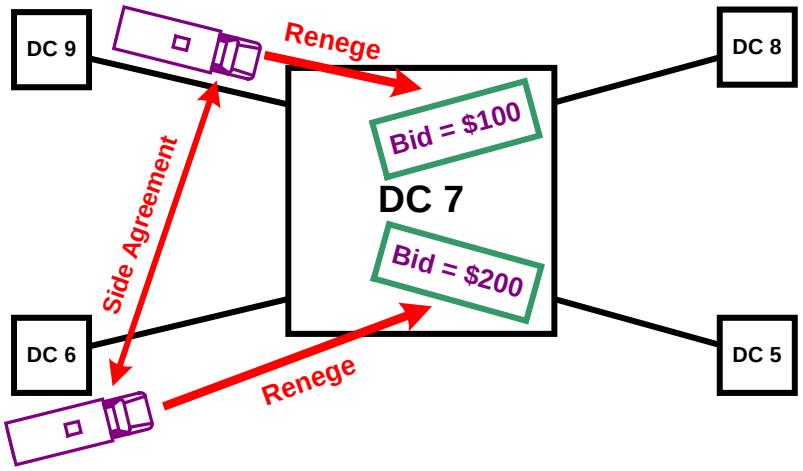


- After reneging, truck cannot again accept same load until all other trucks have rejected it

Near and far trucks accept high and low bids, resp.

Low bid now increases beyond high bid

2. Reneging



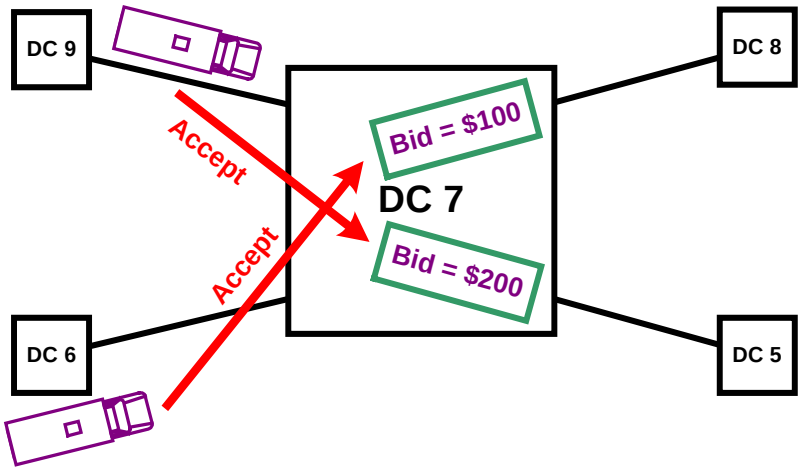
- After reneging, truck cannot again accept same load until all other trucks have rejected it

Near and far trucks accept high and low bids, resp.

Low bid now increases beyond high bid

Trucks agree to renege (since far truck's portion fixed at $50)

2. Reneging



- After reneging, truck cannot again accept same load until all other trucks have rejected it

Near and far trucks accept high and low bids, resp.

Low bid now increases beyond high bid

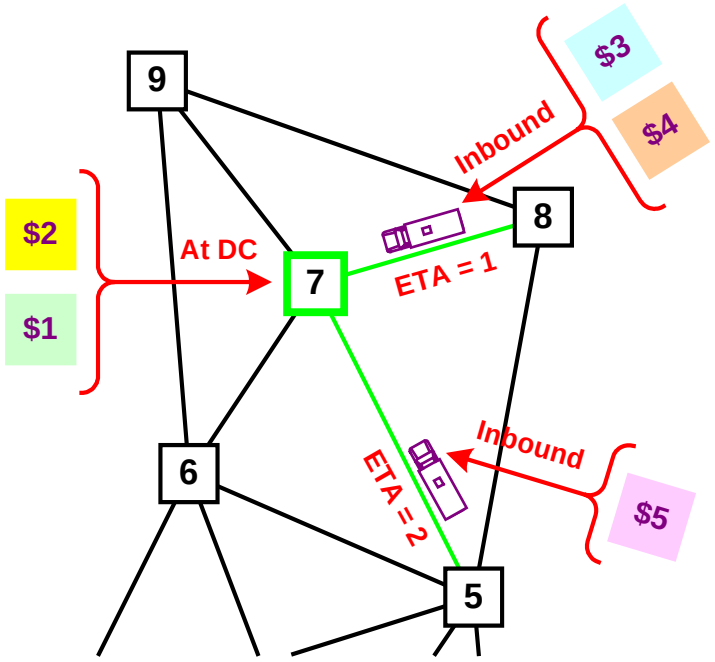
Trucks agree to renege (since far truck's portion fixed at $50)

Near truck accepts $200 bid and far truck $100 bid

Package Protocol

- Determines which packages selected to join load
- Goal for package selection:
  - Encourage a package to submit a bid that represents its true value for transport as soon possible, thereby allowing trucks to be more responsive and discouraging multiple-bid auction-like behavior
- Protocol:
  1. **Load Formation:** Packages assigned to load that maximizes resulting load bid
  2. **Allocation of Load Bid:** Truck's portion of load bid does not increase after acceptance
  3. **Withdrawal and Rebidding:** Packages that withdraw or rejoin load are charged previous bid amounts

1. Load Formation



- Packages assigned to load that maximizes resulting load bid
- Packages can bid as soon as they are at or inbound to DC

Time Index	Load Bid	First Load	Load Bid	Second Load
0	$3	$2 $1		
1	$9	$4 $3 $2	$1	$1
2	$12	$5 $4 $3	$3	$2 $1

2. Allocation of Load Bid

- Truck's portion of load bid fixed after acceptance
- Subsequent increases in bid allocated to packages in load (and remain in load) at time of acceptance

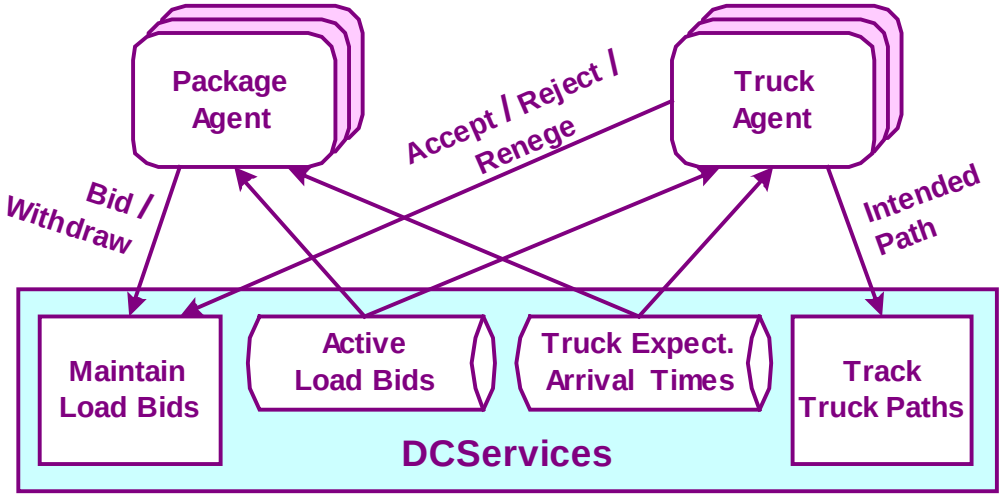
Package Event	Truck Response	Load Bid	Truck Portion	Allocated Portion	Load (Bid / Cost)
Bid & Join	Reject	8	8	0	8 / 8
Bid & Join	Accept	10	10	0	8 / 8 | 2 / 2
Bid & Join	—	15	10	5	8 / 4 | 5 / 5 | 2 / 1
Bid, Join, & Drop	—	16	10	6	8 / 2 | 5 / 5 | 3 / 3 | 2 / 0

3. Withdrawal and Rebidding

- Packages that withdraw or rejoin load are charged previous bid amounts

Package Event	Truck Response	Load Bid	Truck Portion	Allocated Portion	Load (Bid / Cost)
Bid & Join	Reject	8	8	0	8 / 8
Bid & Join	Accept	10	10	0	8 / 8 | 2 / 2
Bid & Join	—	15	10	5	8 / 4 | 5 / 5 | 2 / 1
Bid, Join, & Drop	—	16	10	6	8 / 2 | 5 / 5 | 3 / 3 | 2 / 0
Rebid, Rejoin, & Drop	—	19	10	9	8 /-1 | 5 / 5 | 4 / 6 | 3 / 0
Rebid, Rejoin, & Drop	—	24	10	14	8 /-6 | 6 / 9 | 5 / 5 | 4 / 2
Withdraw & Rejoin	—	28	10	18	8 /-10 | 6 / 9 | 4 / 6 | 0 / 5
—	Renege	28	28	0	8 / 8 | 6 / 9 | 4 / 6 | 0 / 5

Agent-based Coordination



- Each package and each truck controlled by a software agent
- Agents:
  - provided with all load bids at DC and all truck locations
  - can make side payments with each other
  - can be located at DC, off-site via Internet, or in package or truck

Current and Future Work

- Specify DC Services to run at each DC to efficiently support protocol, thereby making larger-scale simulations feasible
- Implement more intelligent (i.e., non-greedy) truck and package software agents
- Explore issues like
  - Dynamic inventory positioning
    - saving on transport cost since it's possible for packages to get "free ride" ($0 bid, only paying for storage)
  - In-transit trading

Contact

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