Less-than-truckload Dynamic Price Optimization in Physical Internet

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Workshop TP2: Physical Internet Analytics and Pricing

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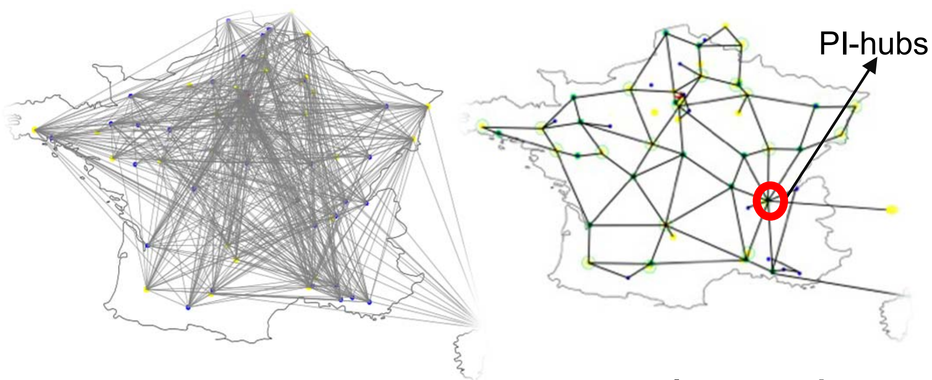
Introduction

○ Allocation problem of shippers' requests in PI

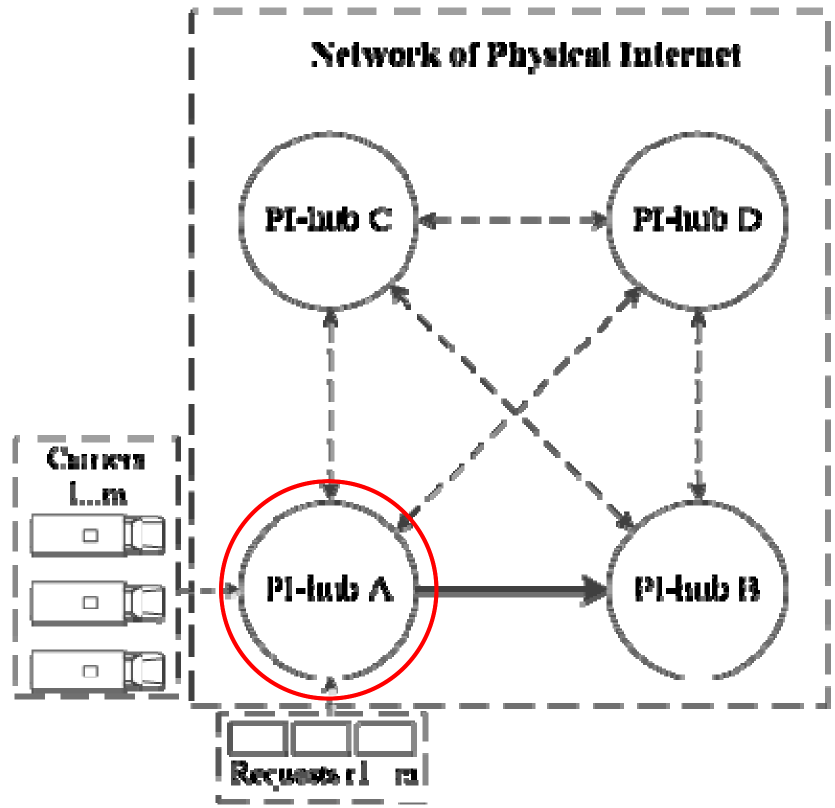
Physical Internet: common open global logistic system (Ballot, Montreuil et al. 2014)

One of important problems: allocation of shippers' requests to carriers.



Current Supply Network **PI - Supply Network**

(source: Ballot, Montreuil et al. 2014)



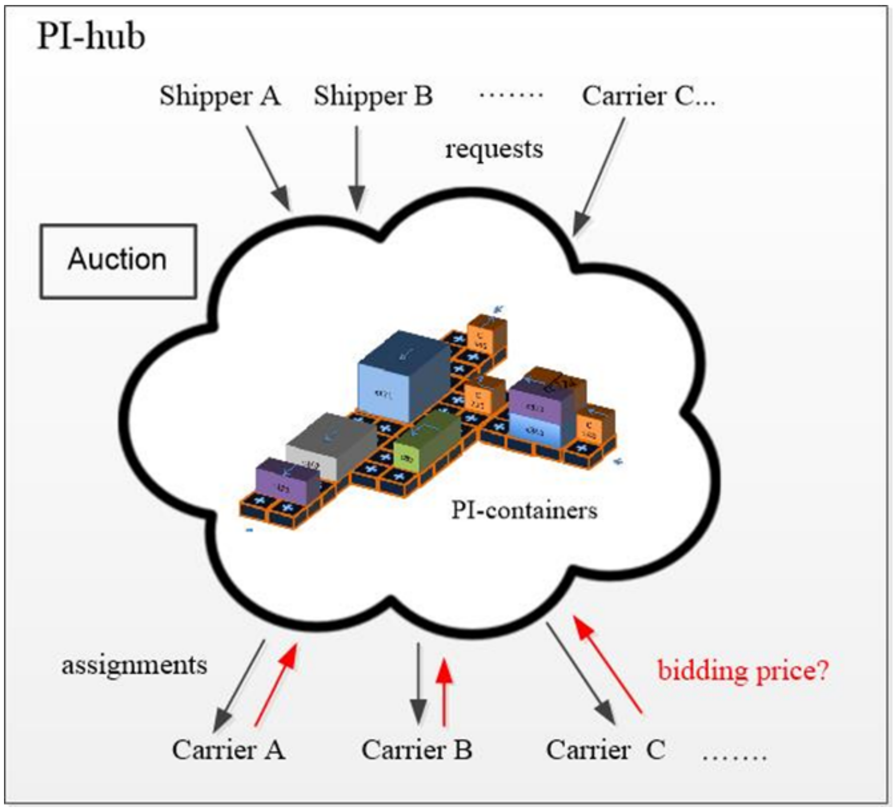
Frequent:

- Requests allocation from shippers to carriers
- Requests reallocation and transshipment between carriers

Introduction

○ Requests allocation in PI-hubs

Previous work: **Auction Mechanism** Pan, S., et al. (2014).



Montreuil, B., Meller, R. D. and Ballot, E. (2010)

Pricing problem appears

Suitable bidding price

⇩

More requests

⇩

More profit

Introduction — related work

○ Pricing problems in transportation industries

- **Similar LTL transportation**

  No auction mechanism

  - **Air cargo** — Allotment. (Kasilingam 1997) (Amaruchkul, Cooper et al. 2007)
  - **Liner shipping** — No competition on price. (Munari 2012) (Uğurlu, Coşgun et al. 2012)
  - **Railway freight** — Fixed rate, scheduling problem. (Crevier, Cordeau et al. 2012) (Kraft 2002)
  - **Intermodal transportation** — Pricing model for mode shift. (Di and Hualong 2012) (Li, Lin et al. 2015)
- **FTL freight transportation** — Pricing time slot, scheduling problem. (Figliozzi, Mahmassani et al. 2007) (Mes, Heijden et al. 2006)
- **LTL freight transportation** — Scheduling and collaboration problem. (L. Barcos, V. Rodríguez et al. 2010)
  Working paper. LTL pricing. (Douma, Schuur et al. 2006)

There is very limited research investigating LTL dynamic (bid) pricing problem in auction mechanism.

Introduction

○ Pricing characteristics of road freight transport in PI

carriers	**sequential**	The current decision will affect the state of the next auction in current or next hub
	capacity-finite	Carrier's capacity would be finite
	time-finite	Carrier's waiting time should be finite
requests	**LTL**	Most of the transport requests in PI-hub are LTL requests
	stochastic	Requests have some stochastic features such as arrival or departure time, size, destination, and planned lane (routing) etc.
	bundle	It means carrier could bid for several requests in a single auction.

Because of the high randomness existed in PI, the pricing problem in PI will be dynamic.

Introduction

○ Gap between pricing in TL/LTL and in PI

(R: request L: lane C:capacity VR: vehicle route)

Mode	Sequential/ Independent S/I	Variable/Fixed V/F				Multiply/ Single M/S	Stochastic/ Determinate S/D	Reference
		R	L	C	VR			
PI	S	V	V	V	V/F	M	S	This research
TL/ Similar TL	S	F	V	F	V	S	S	(Mes and Van der Heijden 2007)
	S	F	V	F	V	S	S	(Figliozzi, Mahmassani et al. 2007)
	S	F	V	F	V	S	S	(Figliozzi, Mahmassani et al. 2006)
	S	F	V	F	V	S	S	(Mes, Heijden et al. 2006)
	S	F	V	F	V	S	S	(Mes, van der Heijden et al. 2010)
LTL/ Similar LTL	I	F	V	V	F	M	D	(Li, Lin et al. 2015)
	S	V	V	V	F	S	S	(Di and Hualong 2012)
	S	F	V	V	F	M	D	(Crevier, Cordeau et al. 2012)
	S	V	F	V	F	M/S	S	(Kasilingam 1997)
	S	F	V	V	F	S	S	(Kraft 2002)
	S	F	F	V	F	S	S	(Douma, Schuur et al. 2006)
	S	F	V	V	F/V	M	D	(Mesa-Arango and Ukkusuri 2013)
TL/LTL	I	F	F	F	F	S	S	(Toptal and Bingöl 2011)

No pricing model can be used in PI

Research problem, questions and methodology

Research problem:

Dynamic pricing problem considering less-than-truckload transport in Physical Internet ---- PI-LTLDP

Research questions:

1. How to decide the bidding price for request?
2. What factors will affect the price and profit?
3. How do the factors impact on pricing decision?

Research methodology:

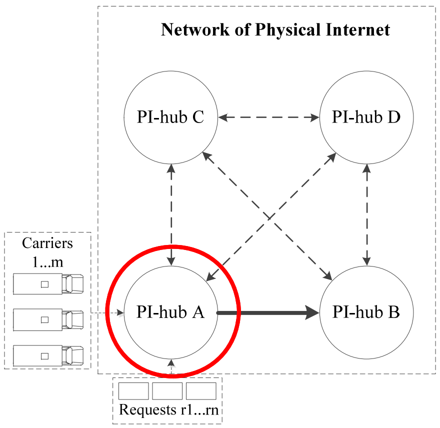
1. Make assumptions of the problem;
2. Design optimization model for dynamic pricing;
3. Numerical experiments;
4. Sensitivity analysis.

Problem Definition — PI-LTLDP

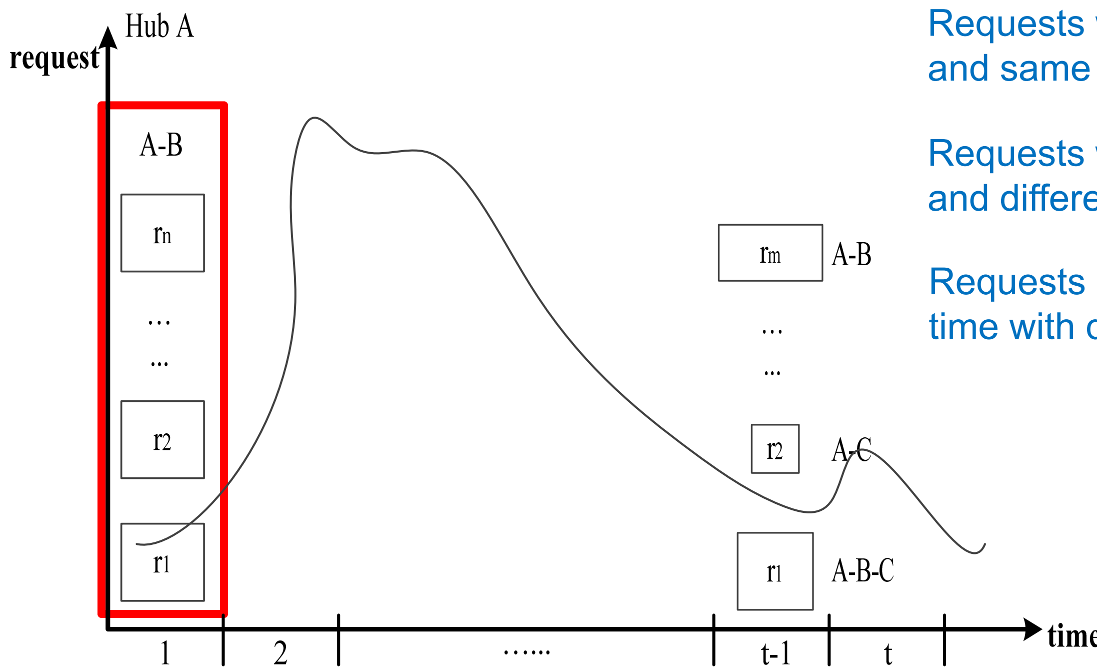
○ Requests flow in PI

In one hub: *m* carriers, r_n requests with different type and routes, carrier bid for all requests in a time unite (an auction period) --> a vector of biding price $\{x_i\}$ with $i=1\ldots t$

Our focus now: in a single time unite, one type of requests, one-leg of requests (one same route)



Simple network of PI



Requests with same size and same route.

Requests with different size and different route.

Requests appear at different time with different quantity.

Requests distribution in hub A

Model

○ Assumptions

1. Auction Mechanism:

(1) first-price sealed-bid auction mechanism

(2) without considering request bundle

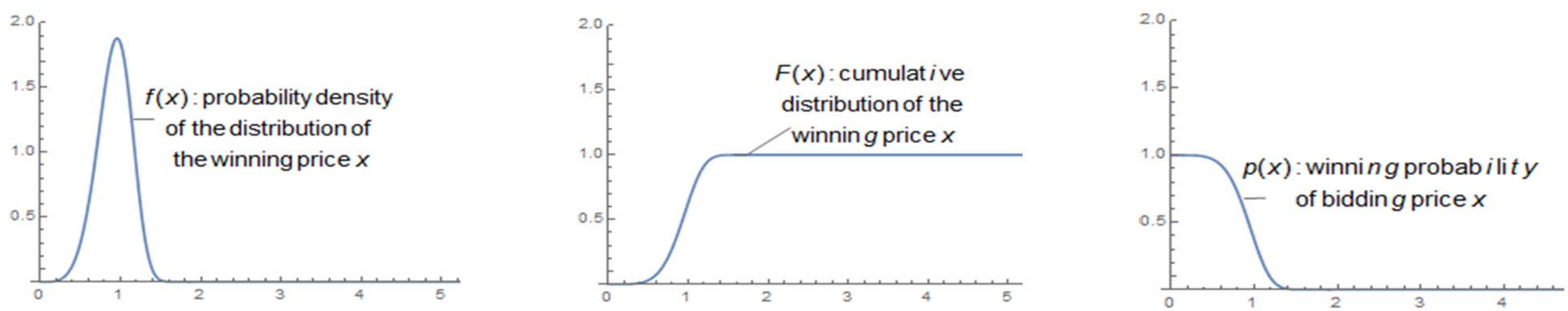
(3) a carrier bids the same price for each request

2. Winning Probability:

Due to lacking of data, we assume the wining prices are distributed according to *Weibull distribution*

(Douma, Schuur et al. 2006)

$$p(x) = e^{-\left(\frac{x}{\lambda}\right)^k}, with\ \lambda = 1, k = 5$$



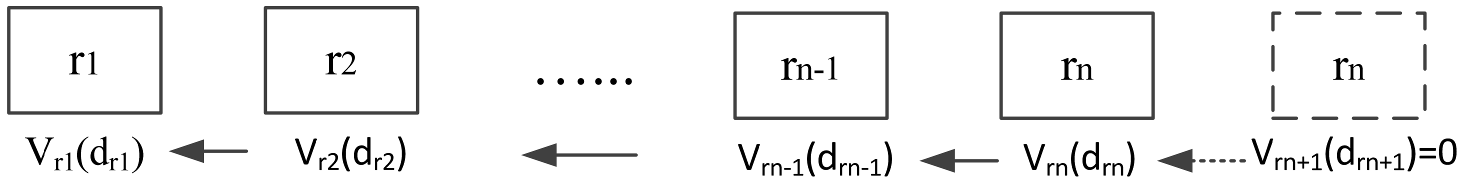
a. probability density of the distribution of the winning price x

b. cumulative distribution of the winning price x

c. winning probability of bidding price x

Model

Dynamic Programming (DP) model: the decision in present state will affect the future state



d_r: the vehicle state, defined with the remaining capacity units when bidding for r request.

$V_r(d_r)$: the expected maximum profit at state d_r.

recursion Model: maximum expected profit at state "remaining capacity *dr*, request *r* " for price $x \in X$

$$V_r(d_r) = \max_{x \in X}[p(x) \cdot [x - c + V_{r+1}(d_r - 1)] + (1 - p(x)) \cdot V_{r+1}(d_r)], \quad r = 1,2, \dots n-1, n$$

boundary condition: capacity sold out or no requests to bid

$$V_r(d_r) = 0, if\ d_r \leq 0\ OR\ r \geq n+1$$

optimal bidding price *x**: optimal bidding price

$$x^* = arg \max_{x \in X}[p(x) \cdot [x - c + V_{r+1}(d_r - 1)] + (1 - p(x)) \cdot V_{r+1}(d_r)], \quad r = 1,2, \dots n-1, n$$

maximum expected profit: maximum expected profit

$$V = \max[V_r(d_r)],\ r = 1,2,\dots n\text{-}1,n$$

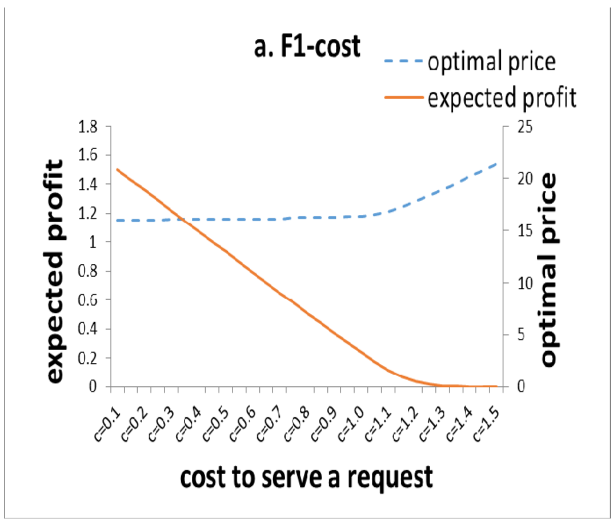
Numerical Experiment

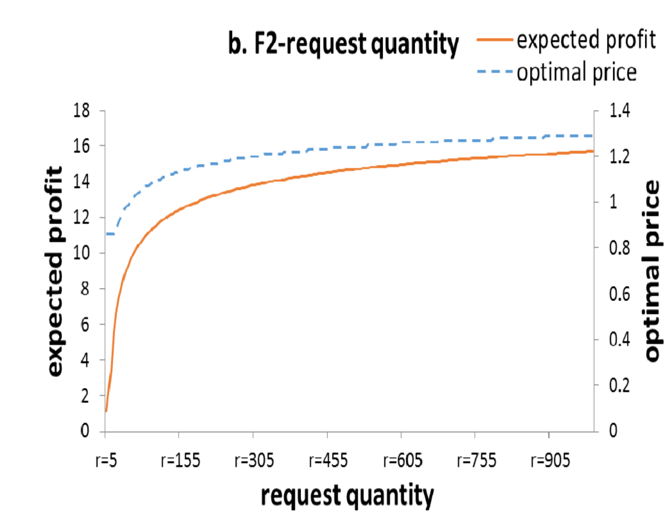
Major factors that could significantly influence the optimal pricing decision?

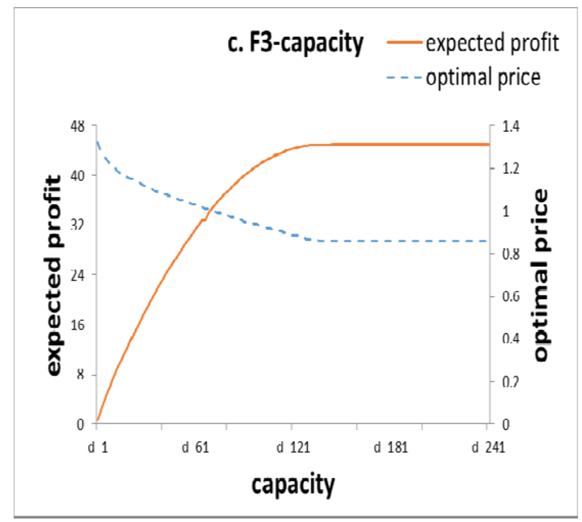
Carrier's actual transport cost; Requests quantity; Carrier capacity

→ Expected profit, optimal bidding price

Investigating Factors	Request quantity	Carrier capacity	Carrier cost
F1-carrier cost	r=200	D=20	0.1≤ c ≤1.5, Step=0.05
F2-request quantity	5≤ r ≤1000, Step=5	D=20	c=0.5
F3-carrier capacity	r=200	1≤ D ≤241, Step=3	c=0.5

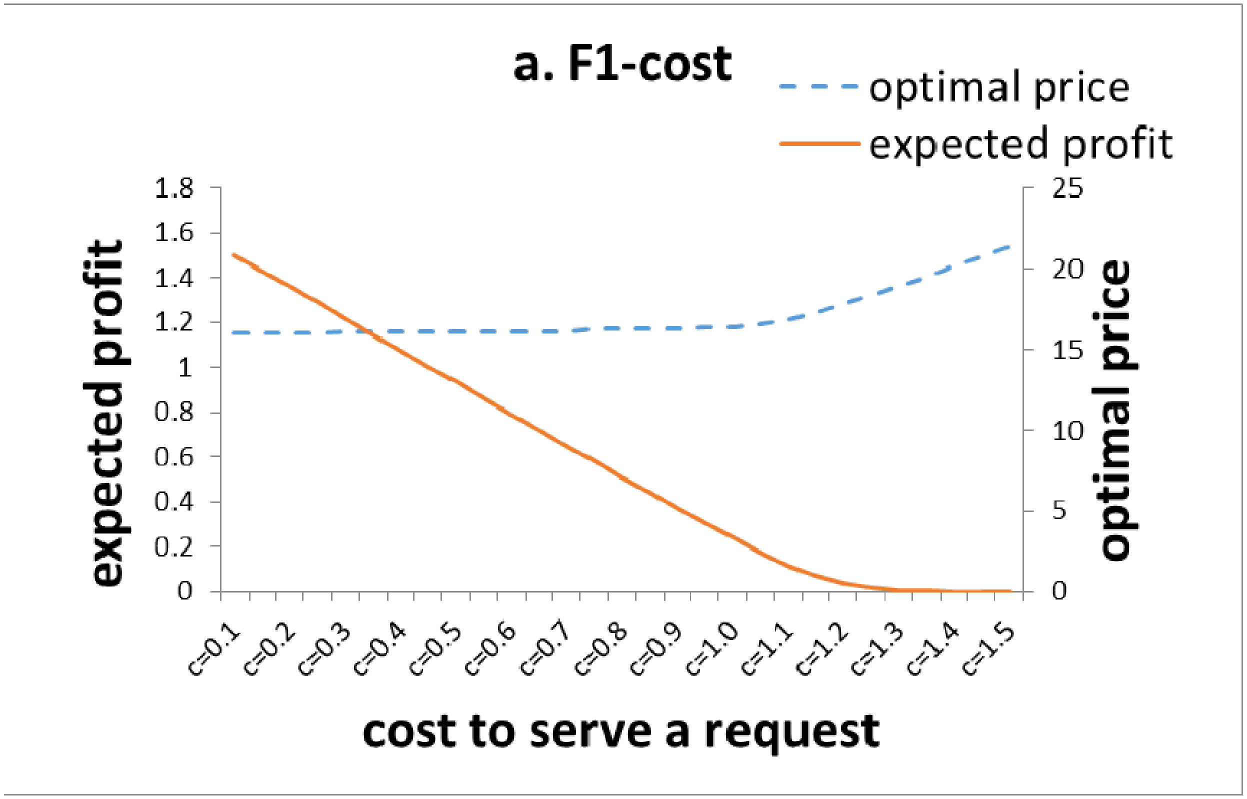






Numerical Experiment

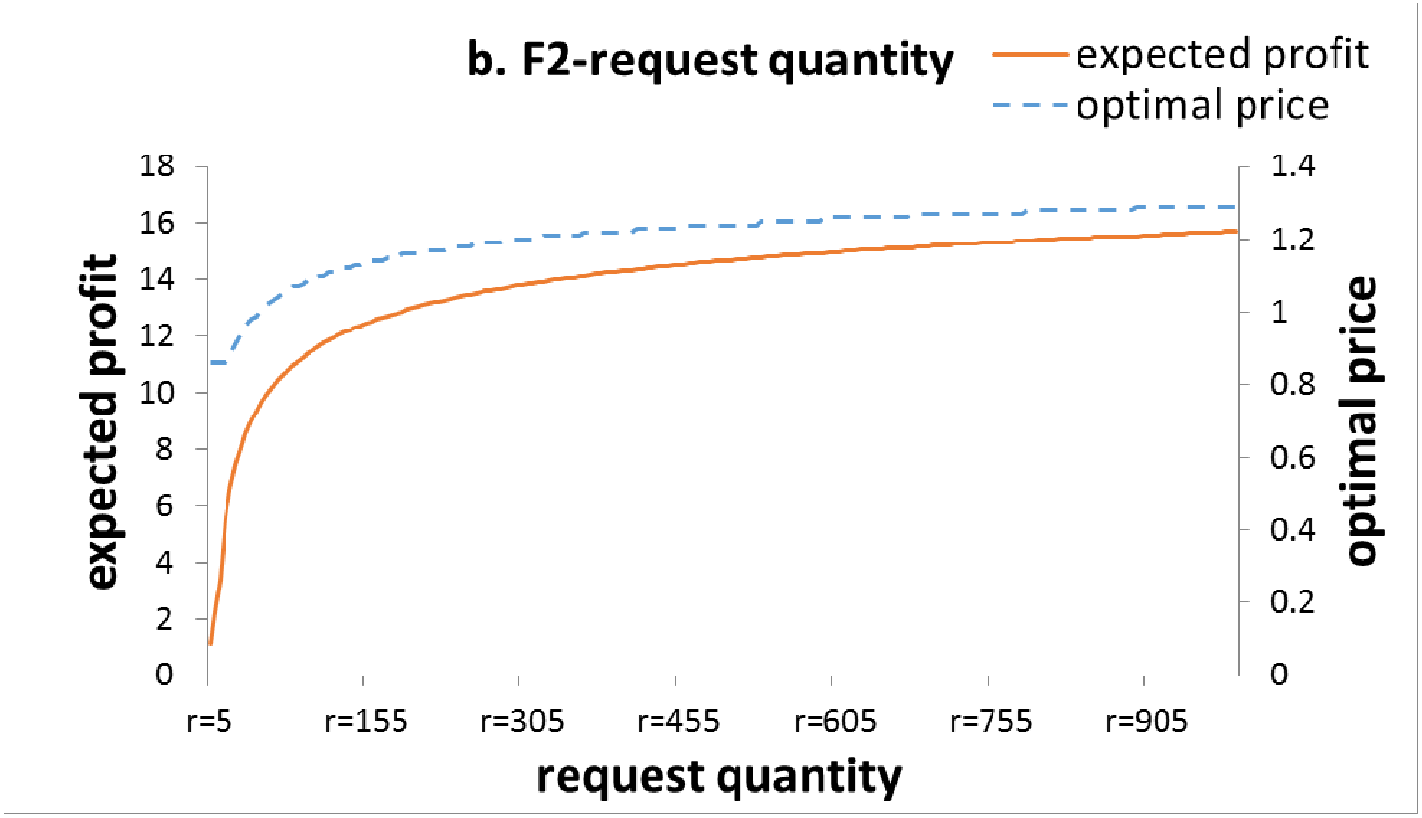
F1 – carrier's transport cost (0.1≤ c ≤1.5, Step=0.05)



1. The *optimal price* increases and *expected profit* decreases conjointly with transport cost.
2. determine the expected profits and pricing strategy when carriers improve their cost.

Numerical Experiment

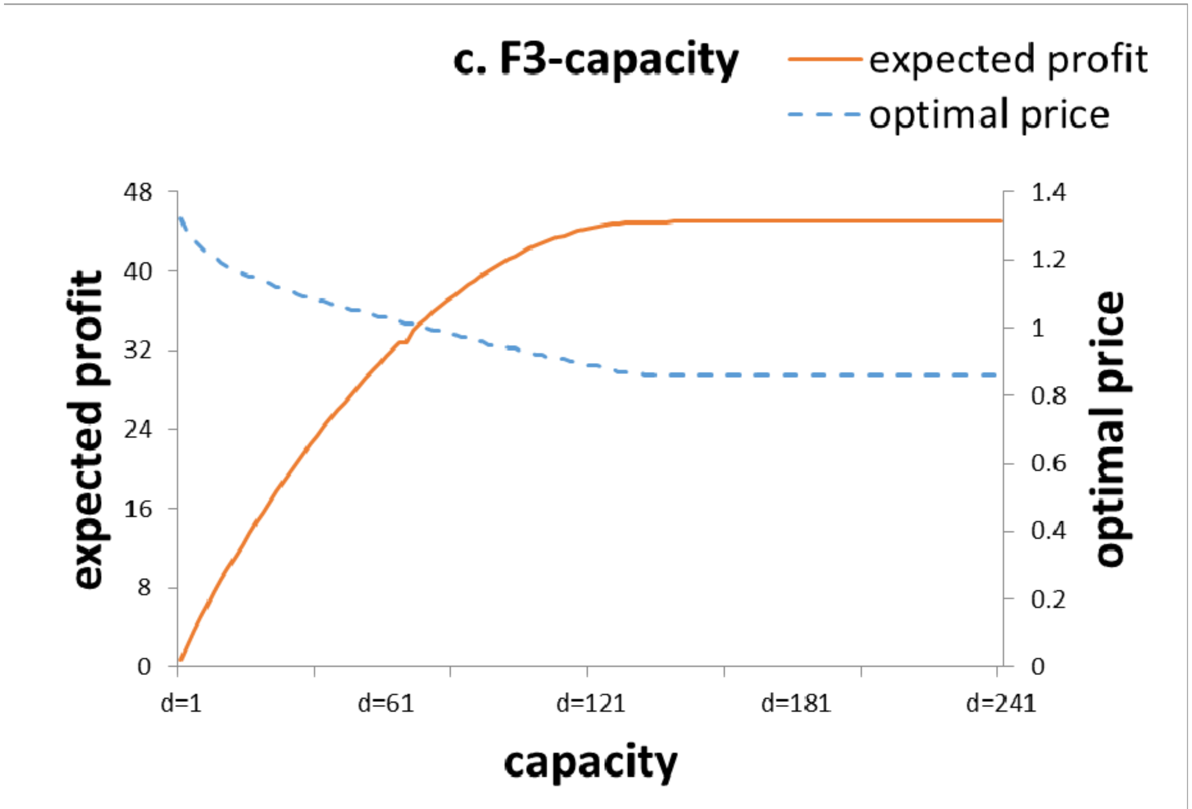
F2 – request quantity (5≤ r ≤1000, Step=5)



1. The *expected profit* and *optimal bid price* all increase along with the increase of requests quantity.
2. Help carriers select the PI-hubs with the highest profit increase rate.

Numerical Experiment

F3 – carrier capacity (1≤ D ≤241, Step=3)



Requests: 200

Turning point: capacity = 137

Price: 0.86

Profit: 45

1. Capacity increase under a turning point, the *profit* is increasing and the *price* is decreasing.
2. Exceeding the turning point, both the *profit* and *price* will stay the same.
3. Help carriers decide allocate how many vehicles facing different numbers of requests estimated.

Conclusion

Contributions:

1. Introduced and defined the PI-LTLDP problem
2. Presented a model to calculate the maximum expected profit and optimal bid price
3. Researched what factors and how these factors affect the result

Limitations:

1. Winning probability: Lack of real data, the winning prices in auctions are assumed now. Need to be validated.
2. Transport cost: Without considering transshipment cost. Transport cost is fixed.

Conclusion

Future work:

1. Impact of **other factors**: auctioning time, route of request and carrier, request size (container type)
2. From the one leg to the **whole network of Physical Internet**
3. **Other actors** in PI, such as shipper, hub controller
4. Apply result into **other open transport networks**, crowdsourcing delivery
5. Apply result into **real market**

Thank you for your attention