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Cooperation in spare parts systems with penalty cost per unit backlogged

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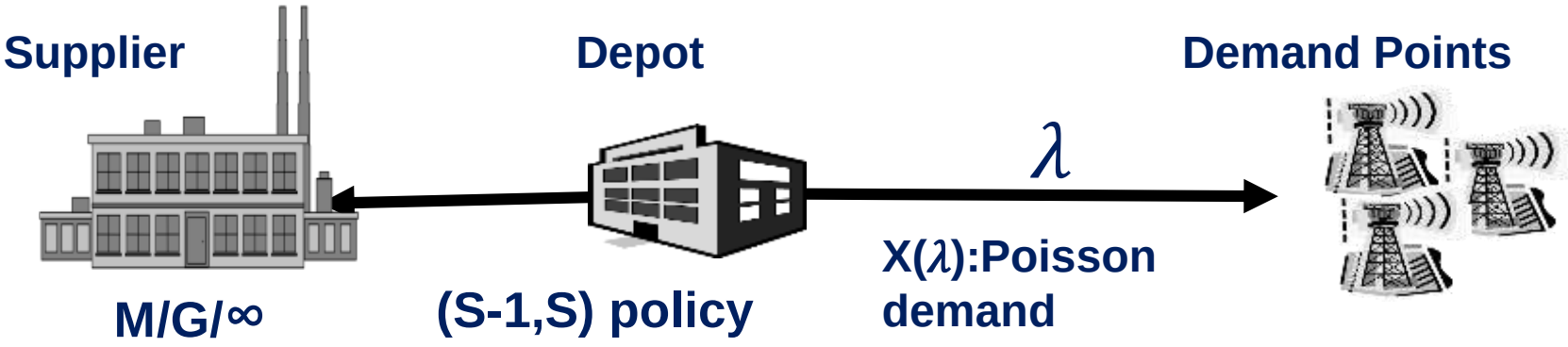
Research Background

- Capital goods: durable goods that is used in the production of goods or services

<u>Common characteristics</u>

- Expensive systems
- High downtime costs
- Expensive spare parts → High inventory cost
- Low utilization → great opportunity of cost reduction by inventory pooling

A spare parts system with penalty cost per unit backlogged



Relevant costs

K(S): Cost of inventory investment

a: one time backlogging cost per unit

Relevant performance measure

BO(S,λ):Average number of items backlogged per unit time

Due to PASTA property, $BO(S,\lambda) = \lambda P(X(\lambda) \geq S)$

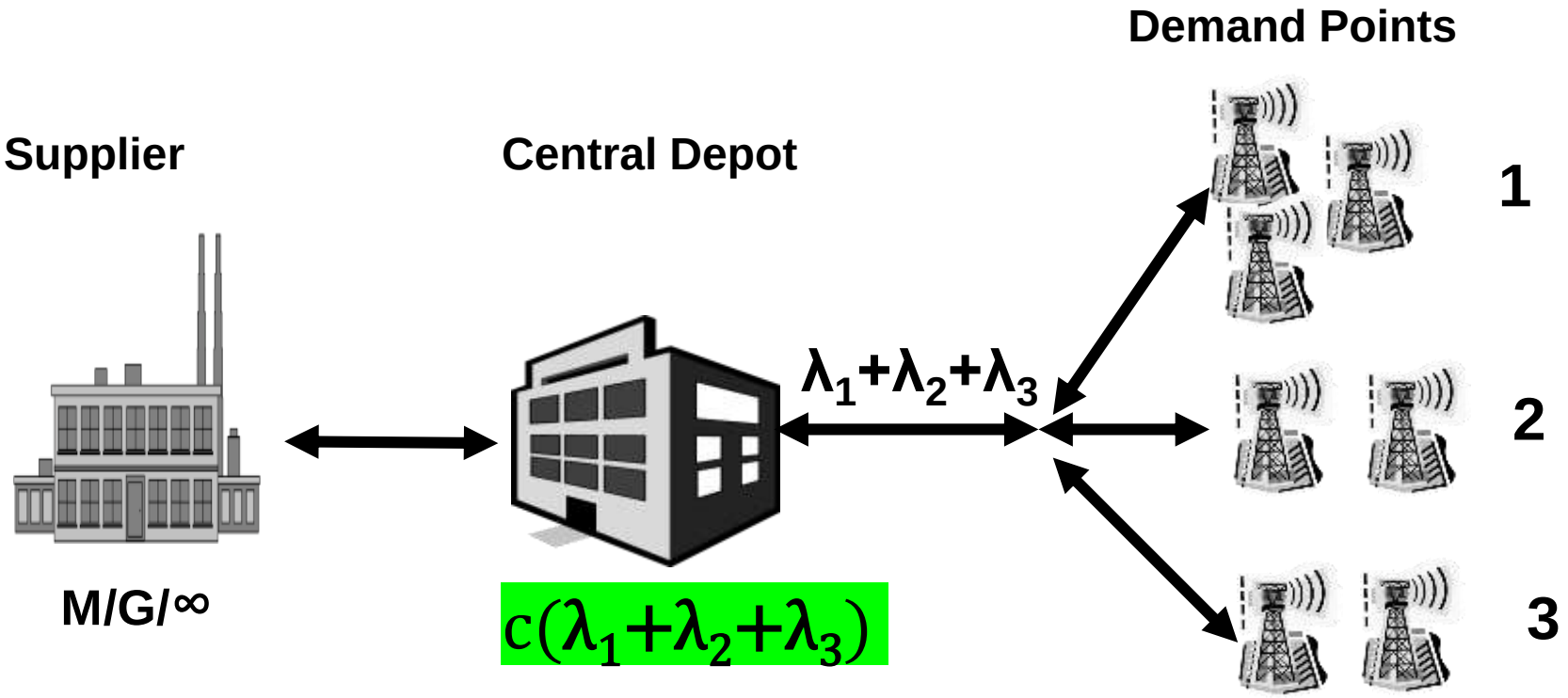
Cost Function

$$\boldsymbol{C(S,\lambda) = K(S) + aBO(S,\lambda)}$$

Optimization Problem

$$\boldsymbol{c(\lambda) = \min_{S \in N^0} C(S,\lambda)}$$

Cooperation Scenario



Benefit:

Total cost of running a central depot will be lower.

Question:

How to allocate the total cost among the coalition members?

Cooperation under optimal inventory investment

- *R={1,…,r}* : the set of companies.
- Every company $i \in R$ *serves the* demand with rate λ_i,

$$c(\lambda_i)$$

- If coalition $T \subseteq R$ is formed, demand rate is $\lambda^T = \sum_{i \in T} \lambda_i$,

$$c(\lambda^T)$$

- *Single attribute game:*
  - *Attributes (λ) are additive:* $\lambda^T = \sum_{i \in T} \lambda_i$
  - *Coalition value is given by a single variable function:* $c\,(\lambda^T)$

How to allocate the cost $\boldsymbol{c(\lambda^R)}$ among the members of the Grand coalition *R* ?

Is the core non-empty?

Key Finding

Theorem 1

- $y_i = \lambda_i c(\lambda^R)/\lambda^R$ for all $i \in R$ is a PMAS and hence a core allocation.

Academic Contribution

- New properties of performance measures (i.e., SH1)
- C(S,λ) is not convex, subadditive or SH1 in general.
- Several subclasses of games with empty Cores
- (cooperation by inventory pooling and under service level constraint)
- Core allocations for the (sub) classes of games with nonempty Cores
- (cooperation under optimal inventory investment, etc..)