

Network Design for Service Parts Logistics

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Service Parts Logistics

- Service contracts guarantee that repair parts/technician will arrive in a given amount of time to fix broken equipment
- Time windows can be as short as two hours
- *Service parts logistics* manages the stocking and transporting of repair parts to satisfy these commitments

Today's Talk

Part I:

A simple problem that can lead to significant savings

Part II:

Extending the problem -- suddenly, it's not so simple!

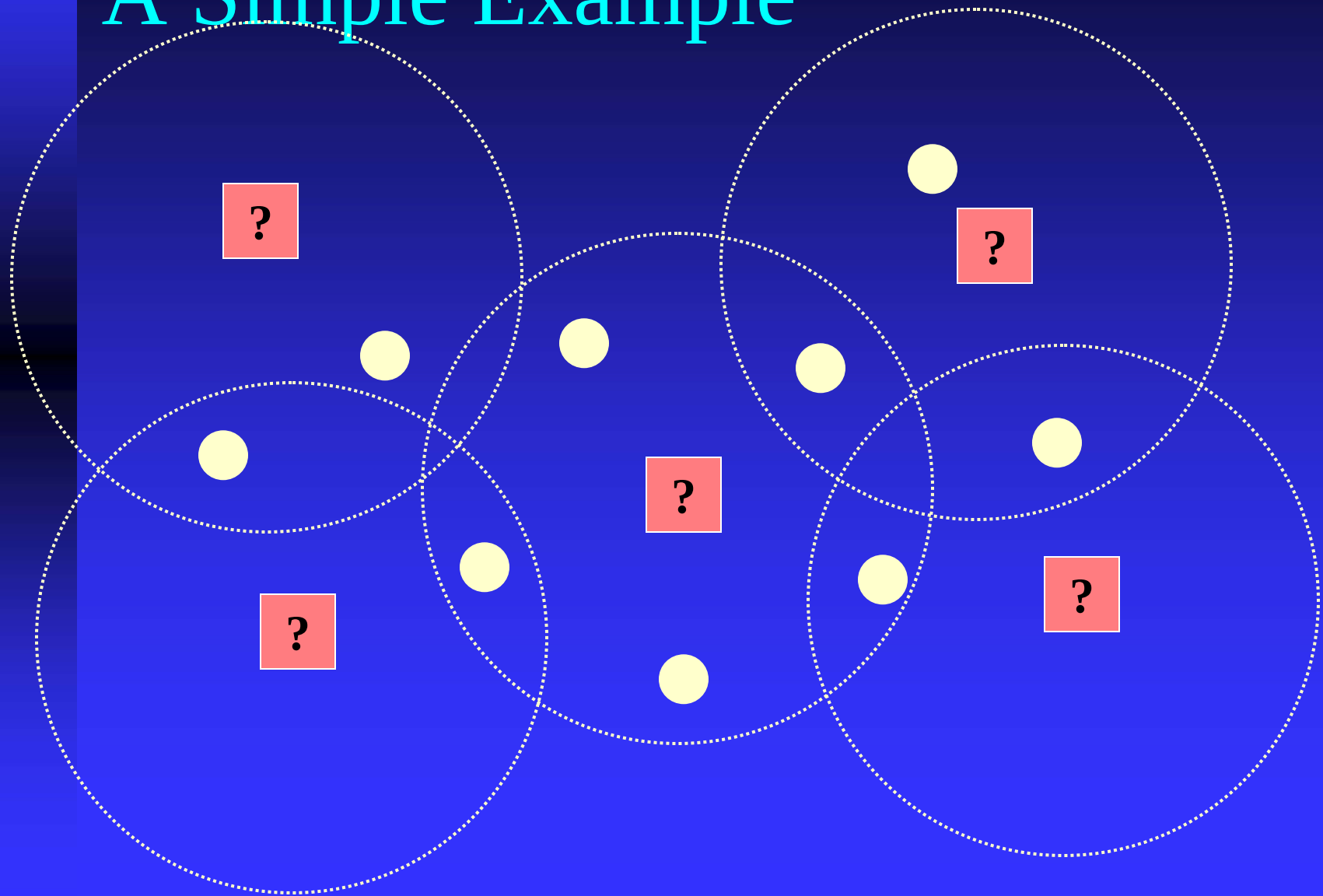
The High-Cost, Low-Demand Stocking Problem

- Special class of parts
- One copy of each part in each warehouse
- Can we decrease the number of warehouses stocking the part and still meet service commitments?

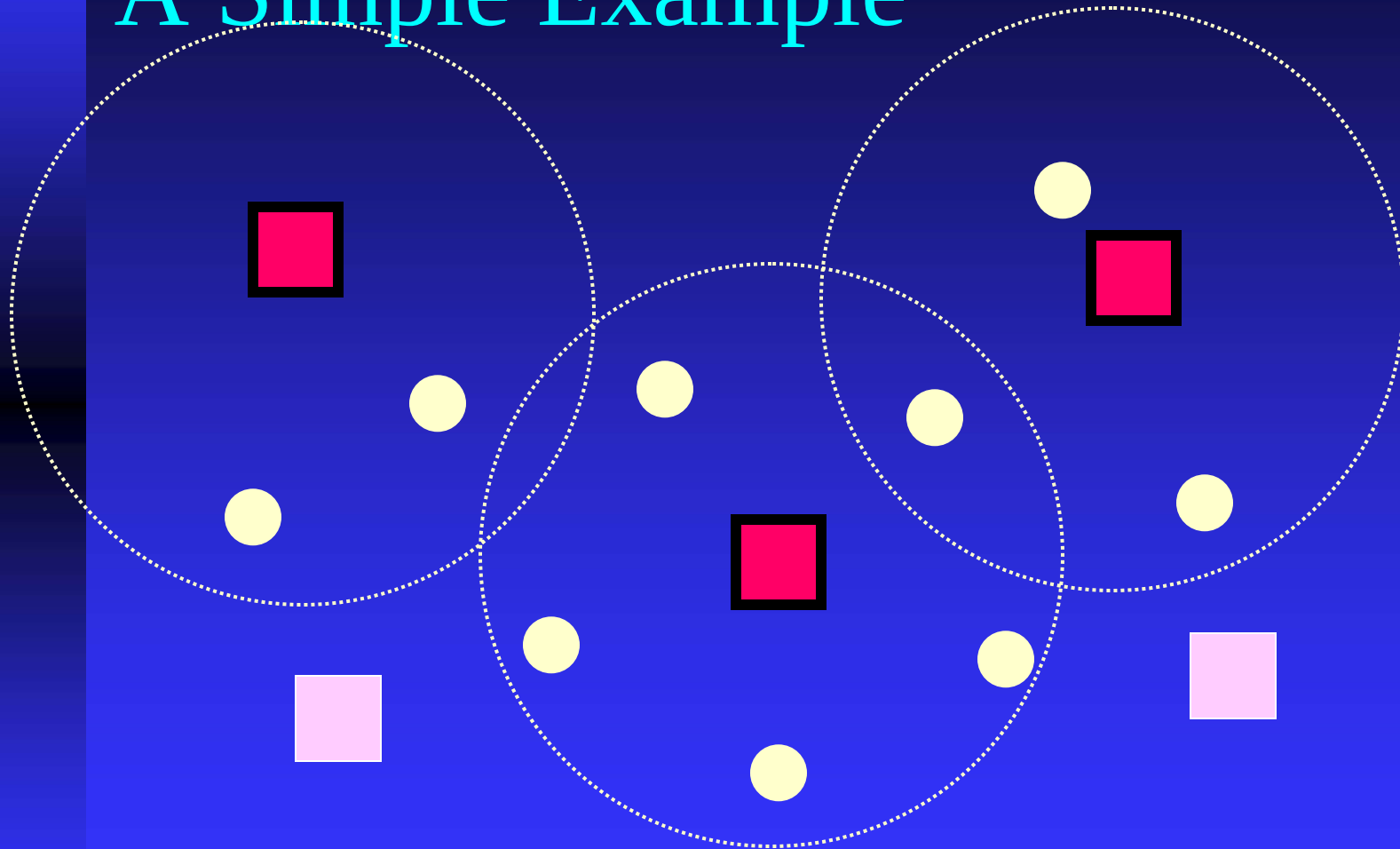
Problem Definition

Given a particular SKU, find the smallest set of warehouses in which to stock it, such that every potential demand for that part is within range of at least one warehouse in the chosen set.

A Simple Example



A Simple Example



Set Covering Model

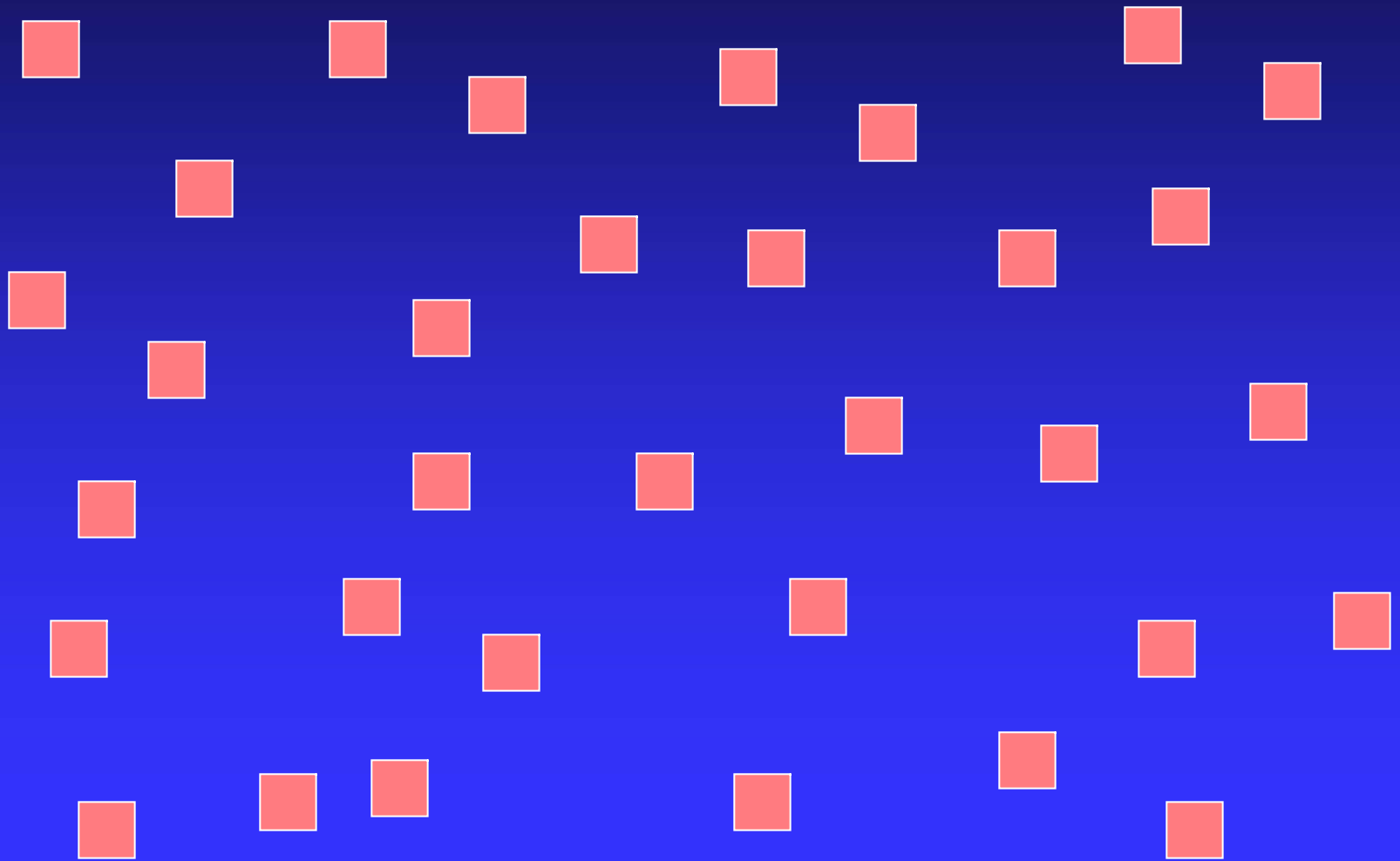
$$\min \sum_{w \in W} c_w x_w$$

st

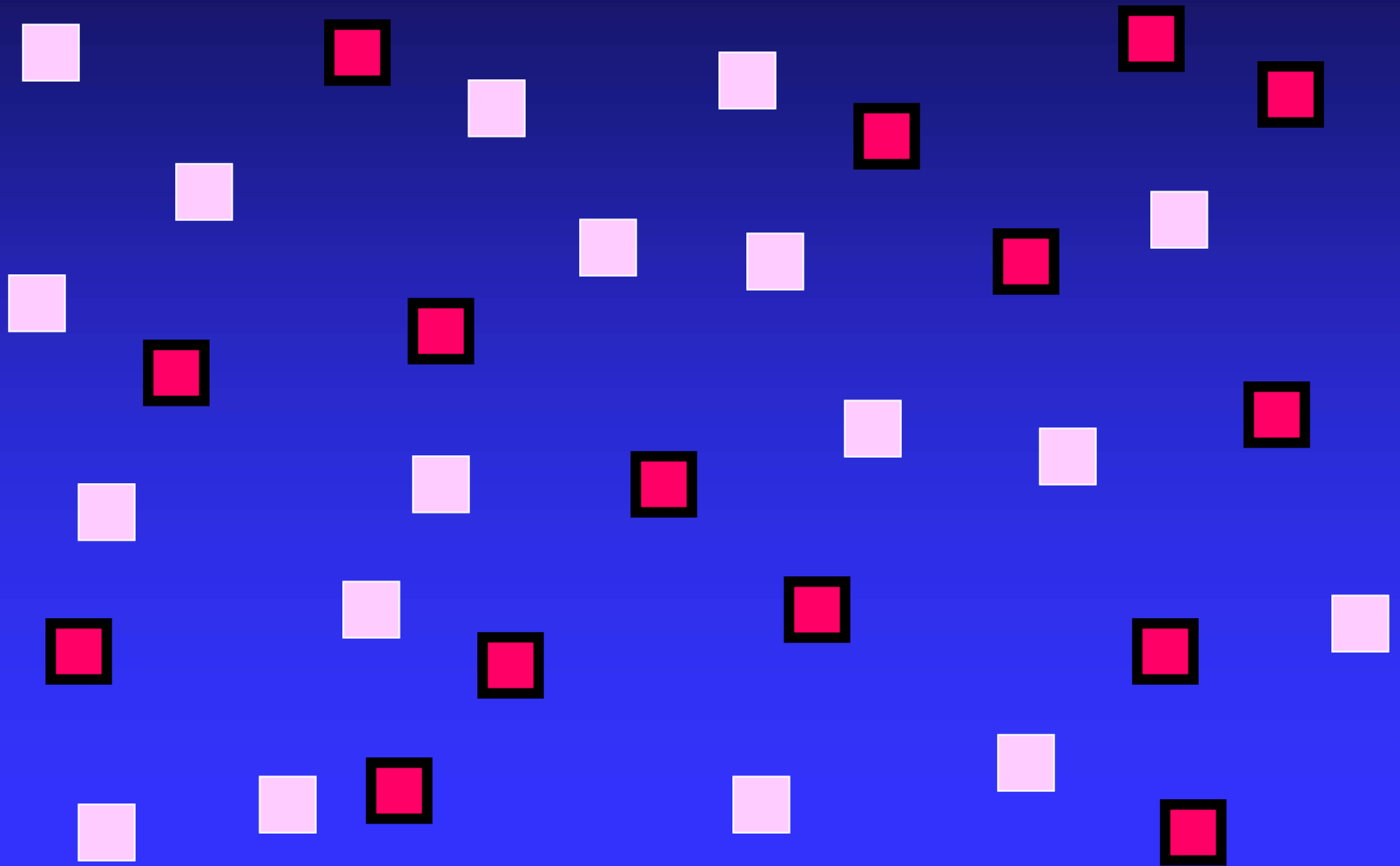
$$\sum_{w \in r(d)} x_w \geq 1 \quad \forall d \in D$$

$$x_w \in \{0,1\} \quad \forall w \in W$$

What is the potential?



What is the potential?



Why is this easy to solve?

- It's a basic set covering problem.
- It's relatively small.
- WE CAN SOLVE EACH SKU INDIVIDUALLY

What makes it hard?

- In broader scopes, we typically can't decompose by SKU
- Problem then becomes very large
- Example: Add in warehouse capacity constraints

The Capacitated High-Cost, Low-Demand Stocking Problem

Given a set of SKUs, a demand set for each SKU, and a set of warehouses with limited capacity, find the minimum cost assignment of SKUs to warehouses such that each demand is covered and capacities are not exceeded.

Basic Formulation

$$\min \sum_{s \in S} \sum_{w \in W} c_{sw} x_{sw}$$

st

$$\sum_{w \in r(d)} x_{sw} \geq 1 \quad \forall s \in S, d \in d(s)$$

$$\sum_{s \in S} w_s x_{sw} \leq CAP_w \quad \forall w \in W$$

$$x_{sw} \in \{0,1\}$$

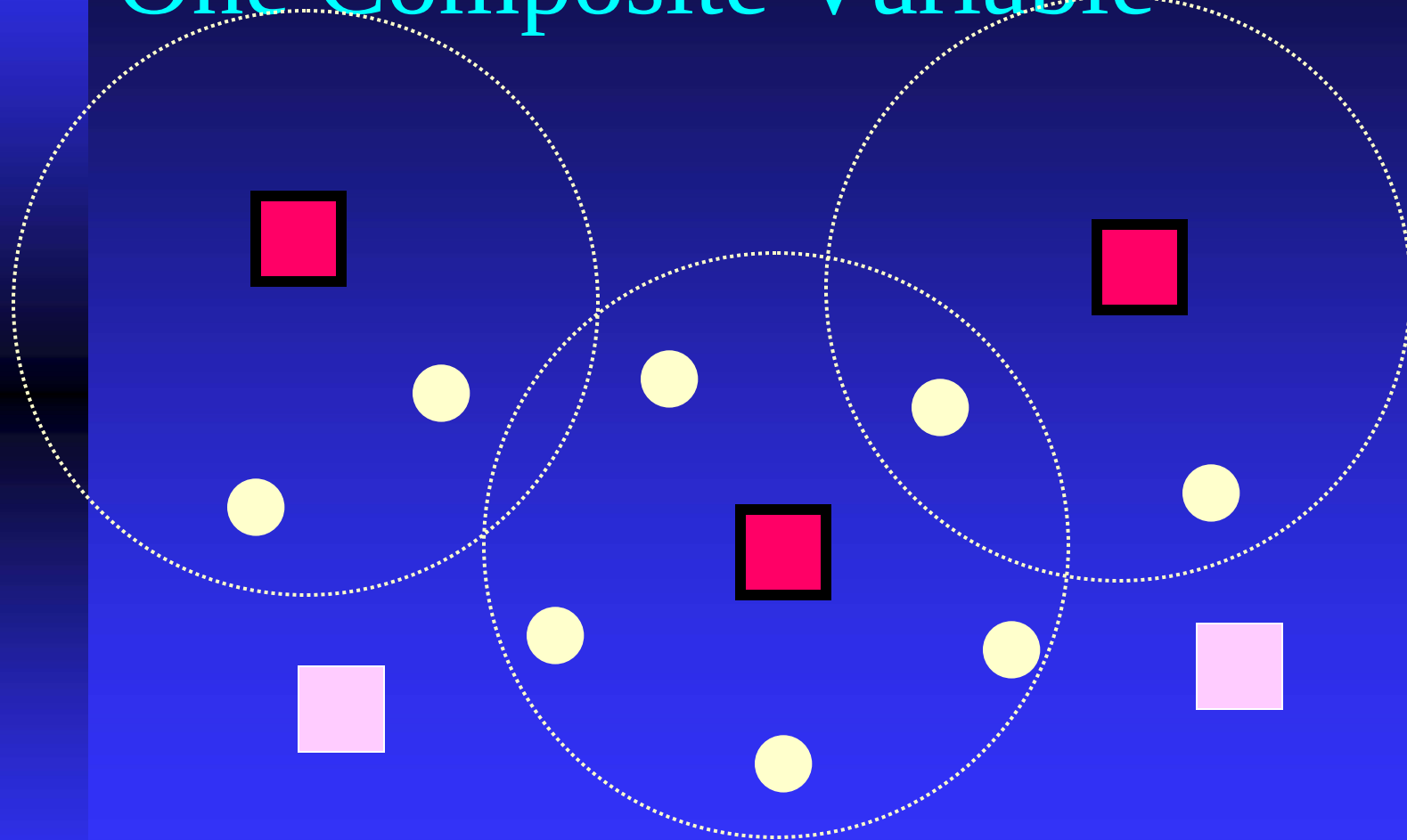
Why is this hard?

- Larger number of binary decision variables
- Very large number of constraints
- Greater tendency towards fractional solutions to the LP relaxation
- Degeneracy

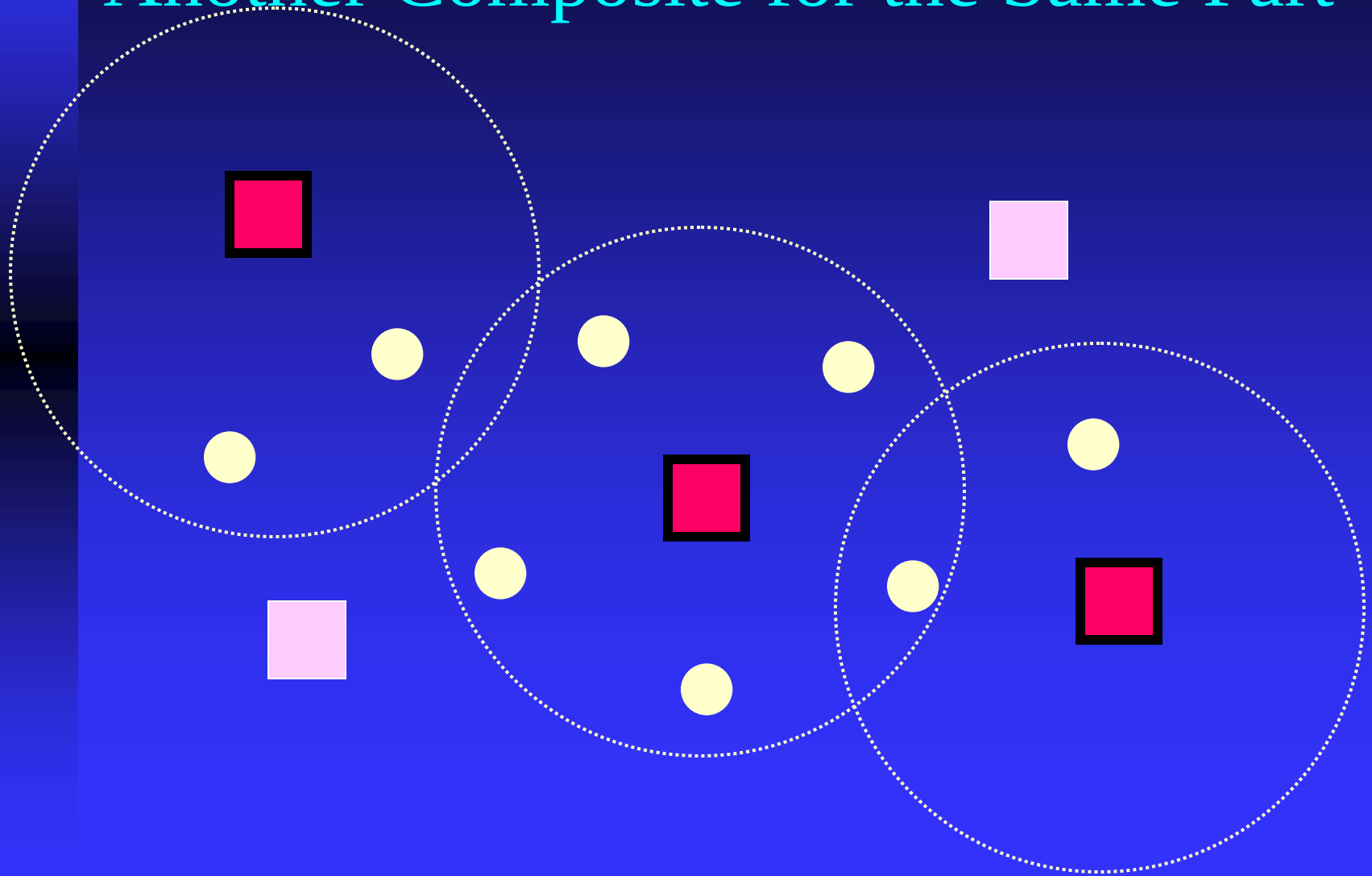
An Alternative Approach

- Let g be a group of warehouses that satisfy all demands for some part s
- Let G_s be the set of all such groups for part s
- $x_{sg} = 1$ if group g stocks part s , else 0

One Composite Variable



Another Composite for the Same Part



New Formulation

$$\min \sum_{s \in S} \sum_{g \in G_s} c_{sg} x_{sg}$$

st

$$\sum_{g \in G_s} x_{sg} = 1 \quad \forall s \in S$$

$$\sum_{s \in S} \sum_{g \in G_s : w \in g} w_s x_{sg} \leq CAP_w \quad \forall w \in W$$

$$x_{sg} \in \{0,1\}$$

Isn't this even bigger?

- In theory, we have an exponential number of binary decision variables
- In practice, we use column generation and only include a fraction of the variables
- Duals guide us to good warehouse groups
- Pricing problem is just the uncapacitated single part problem
- Dominance

Theoretical Observations

- Many fewer constraints
- LP relaxations are tighter
- Potential heuristic use

Solving the Composite Model

Solve each LP with
column
one price
per SKU
part stock

Branch on SKU/
pairs

Depth-first until first
integer solution found,
then best-bound to
search the tree

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Computational Results

Problem	Time	Time	Opt	# Nodes	# Columns	# Nodes	# Nodes	# Columns
Instance	Basic	Comp	Val	Basic	Comp.	Basic	Comp.	Comp.
					20	1		
1	16	9		1,000	90	1	10	1
2		47		837	260	3	1,000,000	1
3		129			260	1	837,500	3
4	9	242	Inf		20	1	1	1
5	13	18			84	1	14	1
6	51	90			163	1	1200	1
7	15,167	162		412	258	1	412,939	1
8	8	265	Inf		267	1	1	1
9	113	273	Inf		20	1	1	1
10	13	19			20	1	10	1
11	13	18			20	1	10	1
12	15	119			67	16	1	16
13	150				NA	NA	2800	NA
14	11,653	760			131	91	174,400	91
15	26	189			74	33	100	33

Future Directions

- Conduct further testing on the current problem
- Expand problem definition to take into account more of SPL issues
- Generalize techniques of composite variable modeling

Conclusions

- Significant benefits can often be gained by examining small parts of a problem
- These problems can become very difficult when extending them
- Composite variable modeling can often be useful in such cases