Combining Graph Contraction and Strategy Generation for Green Security Games

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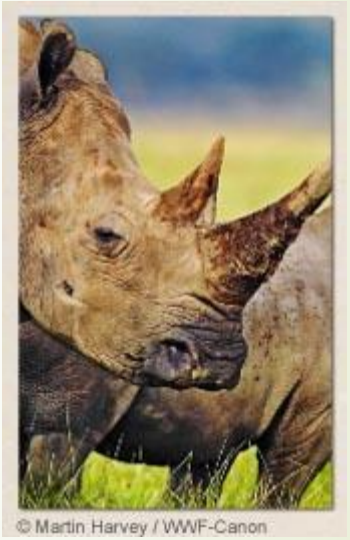
Environmental Crimes

Illegal fishing

Illegal logging



Poaching

Consequences

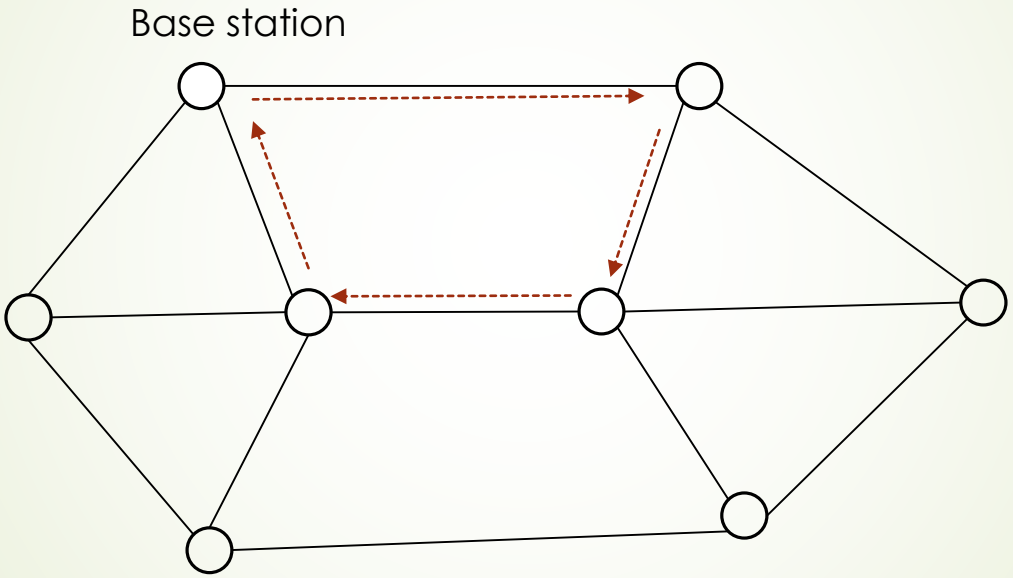
- Major threat to biodiversity
- Global warming
- Financial loss

Stackelberg Security Game(SSG)

Green Security Game(GSG)

- Graph based representation of terrain (e.g. national park)
- Node represents a small portion of the terrain(1kmx1km)
- Attacker: poacher Defender: patroller
- Solution: Optimized patrolling strategy

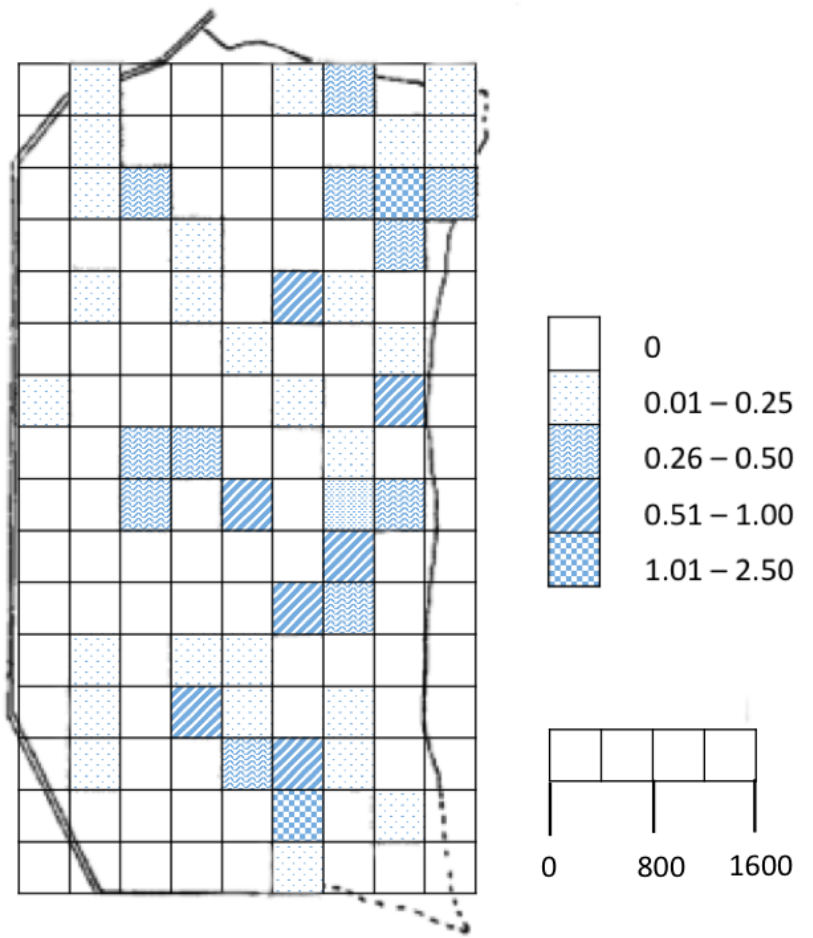
Patrolling Path in GSG



Problem

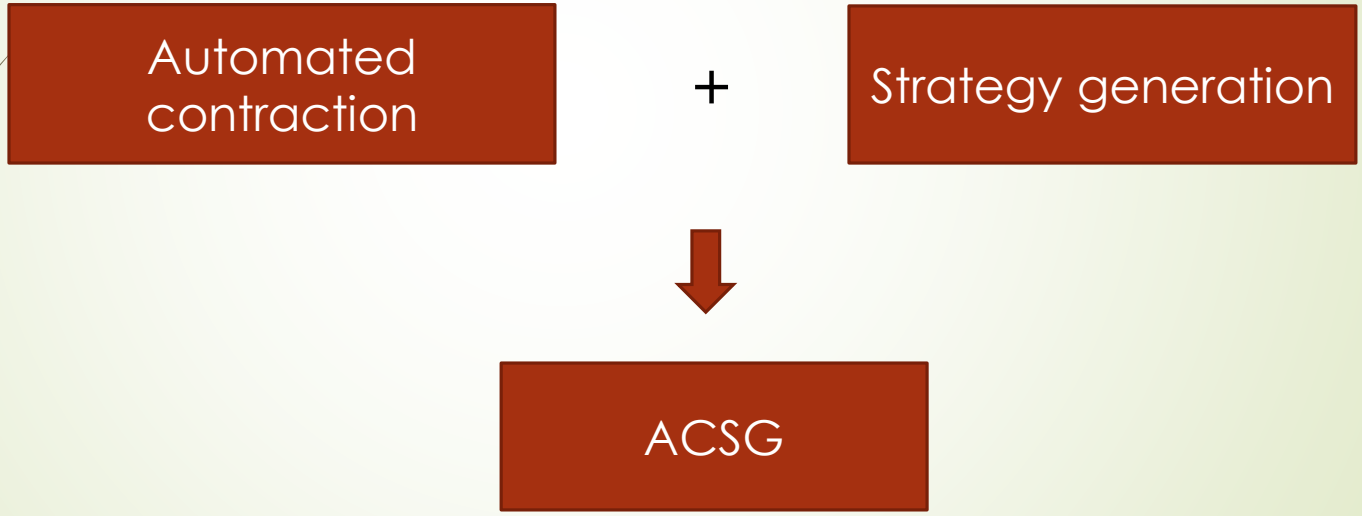
- Huge area
- Exponential number of paths
- LP optimizes over all of the paths.
- Largest problem solved : 25 targets(approximately)

Motivation

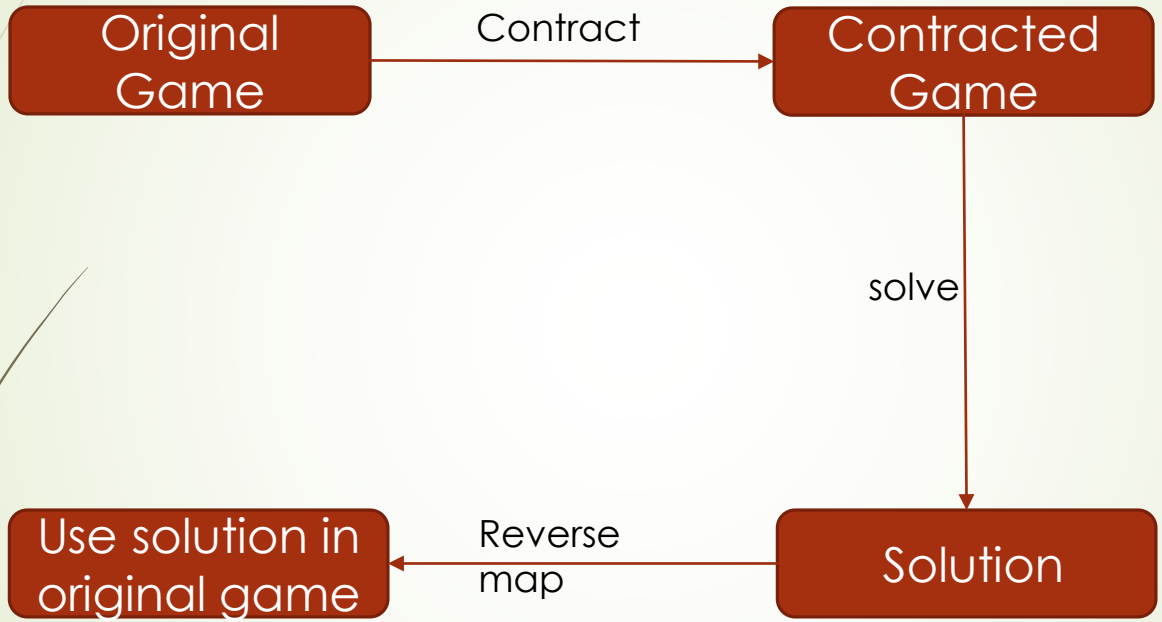


Mean numbers of elephants/0.16km^2 in Queen Elizabeth National Park, Uganda

Solution Idea



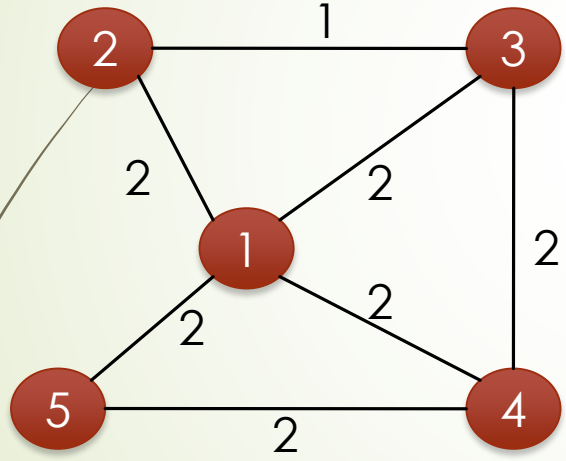
Abstraction Using Graph Contraction

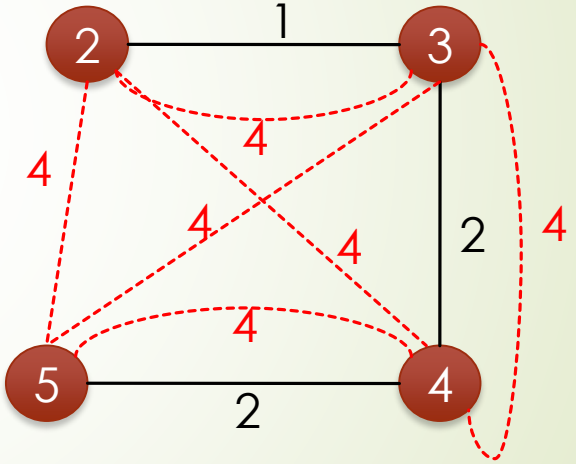


Contraction

- Removes unnecessary nodes one by one
- Introduces edges
- Evaluates edges whether to keep or not

Contraction

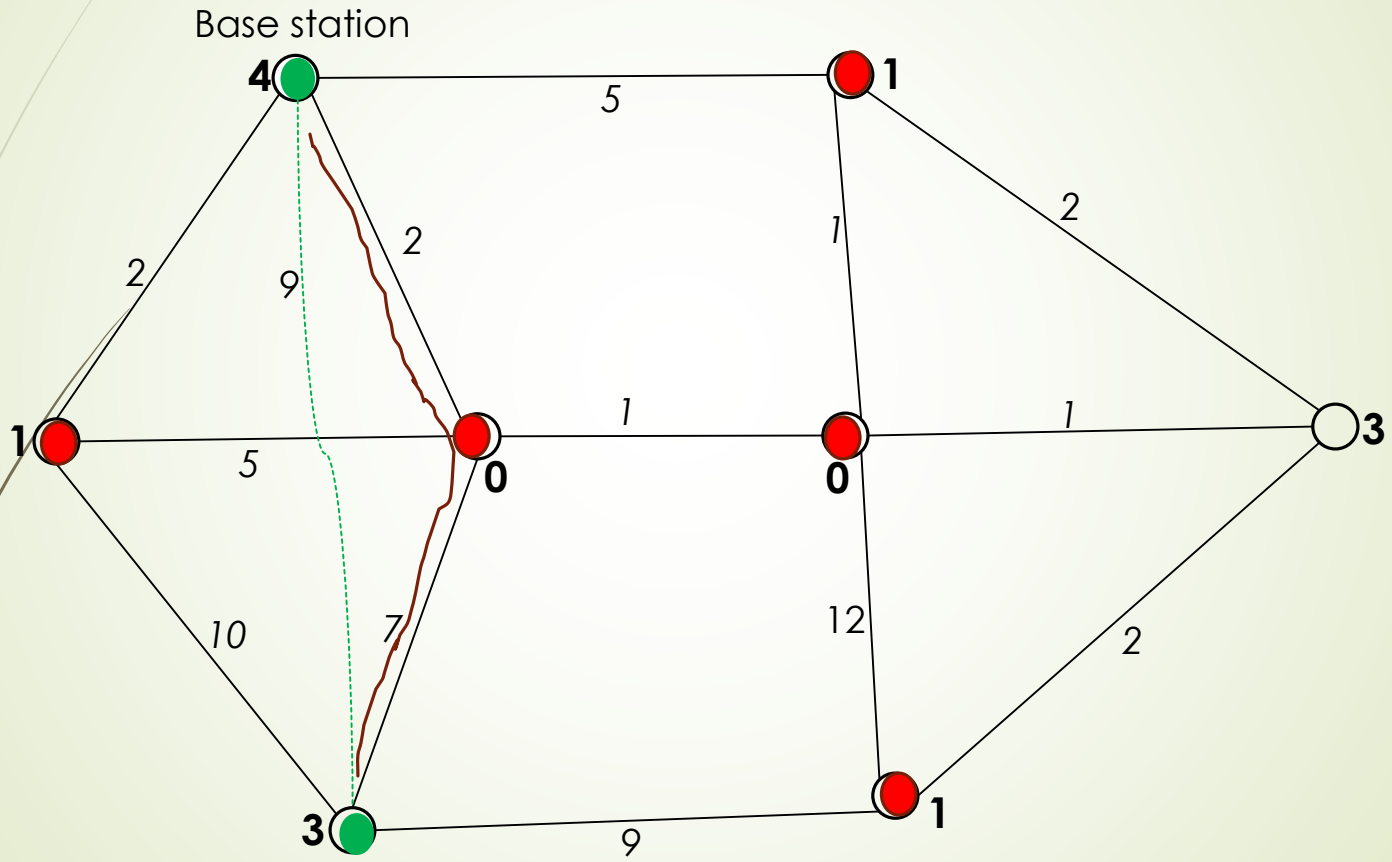




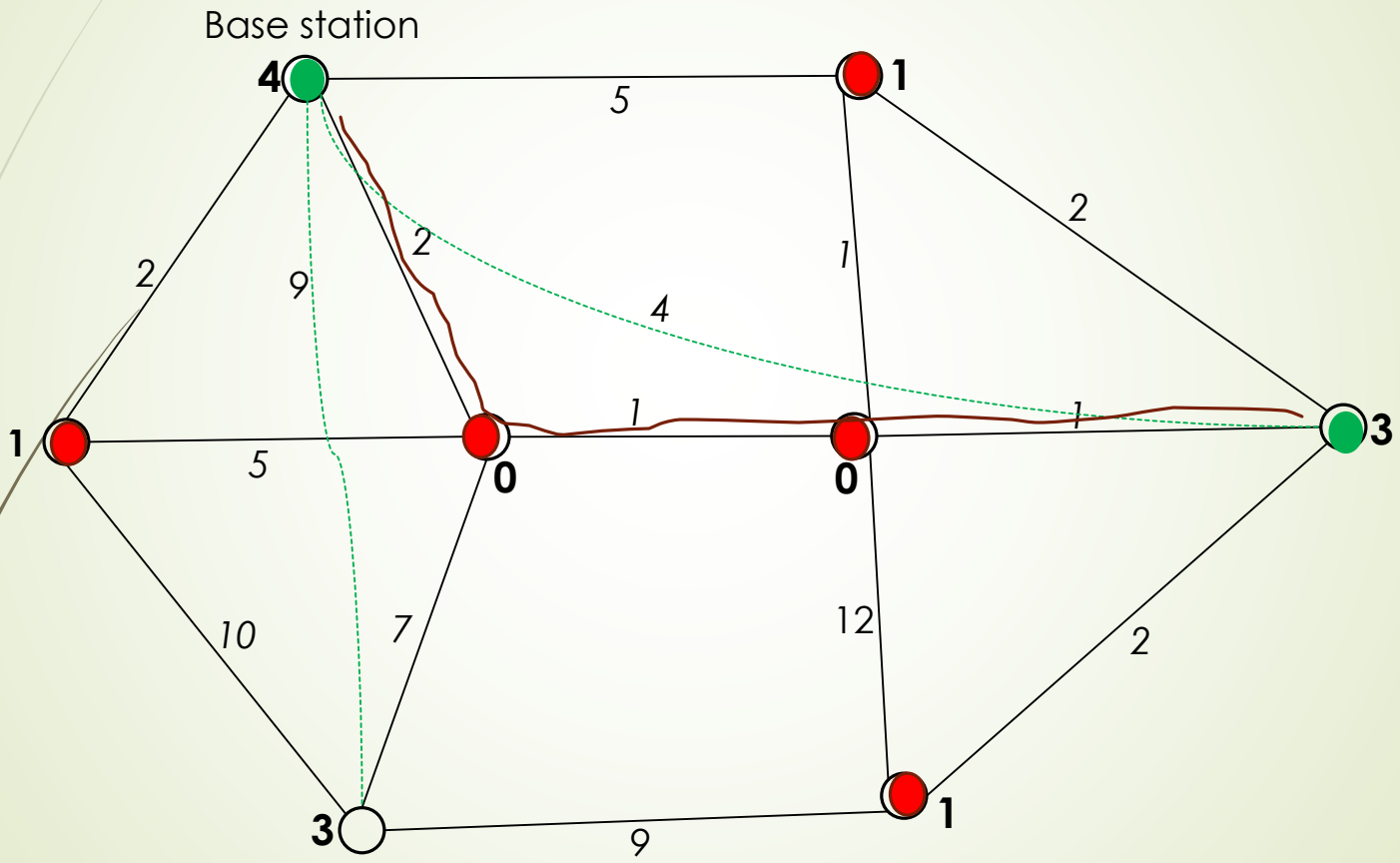
Instant Contraction

- Removes unnecessary nodes altogether
- Finds shortest path through unnecessary nodes

Instant Contraction



Instant Contraction



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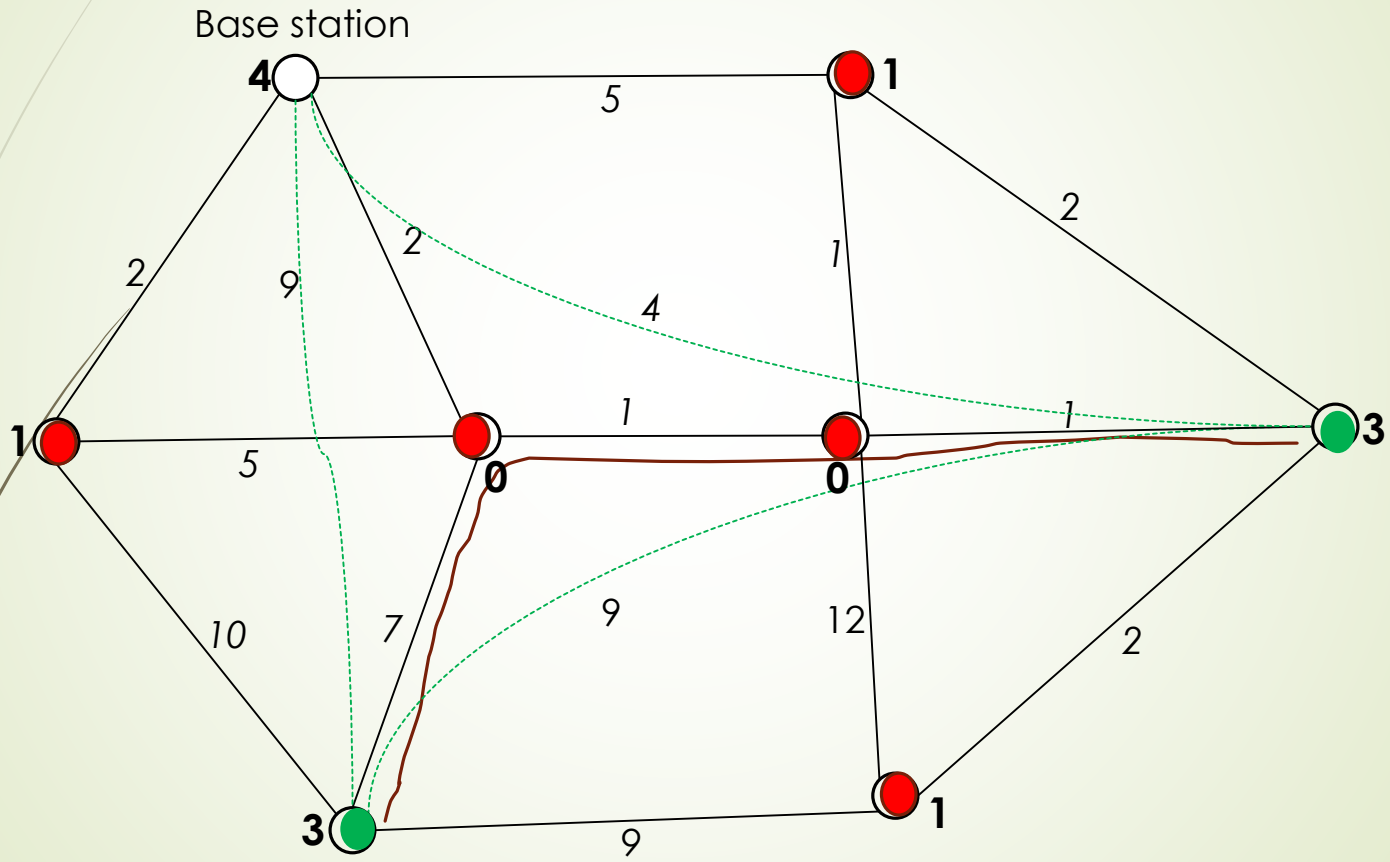

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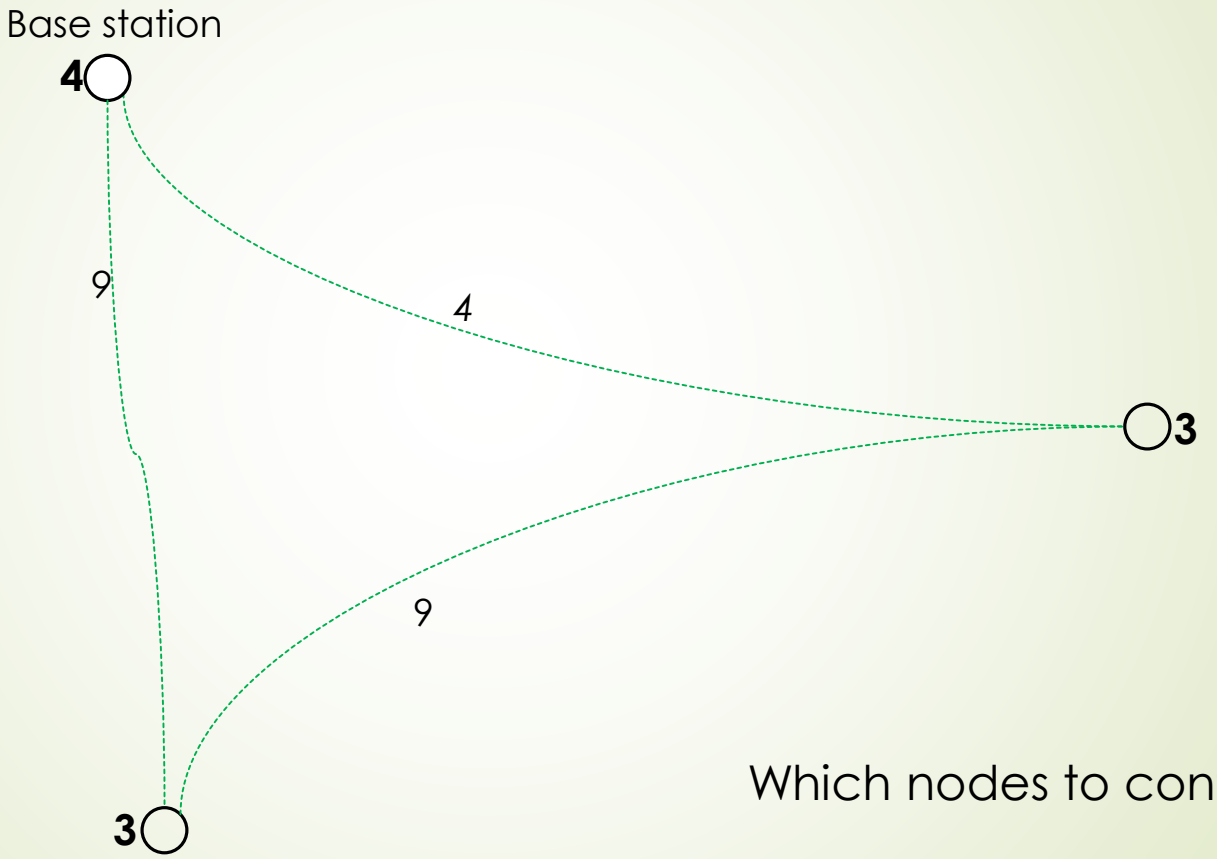
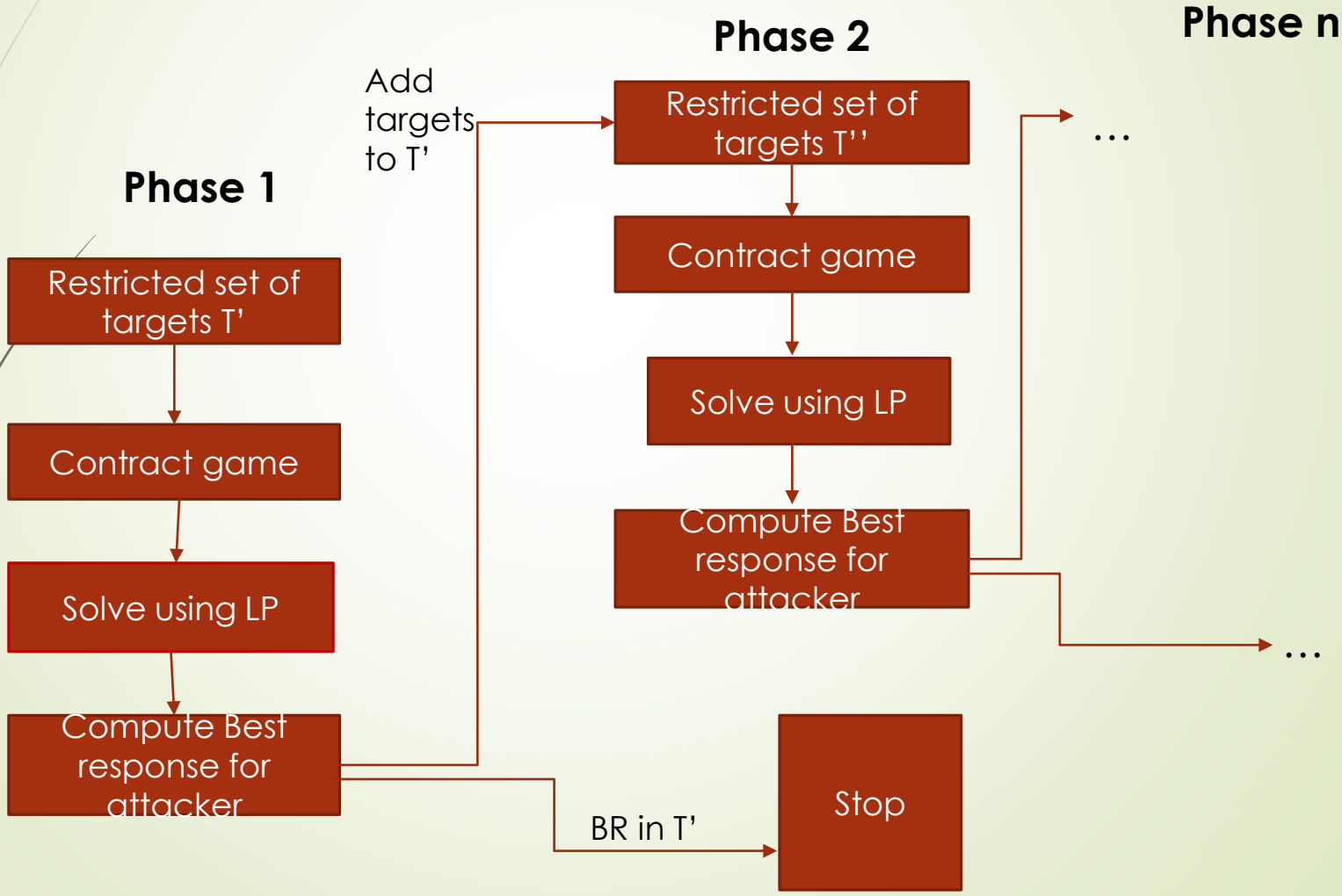


Which nodes to contract ?

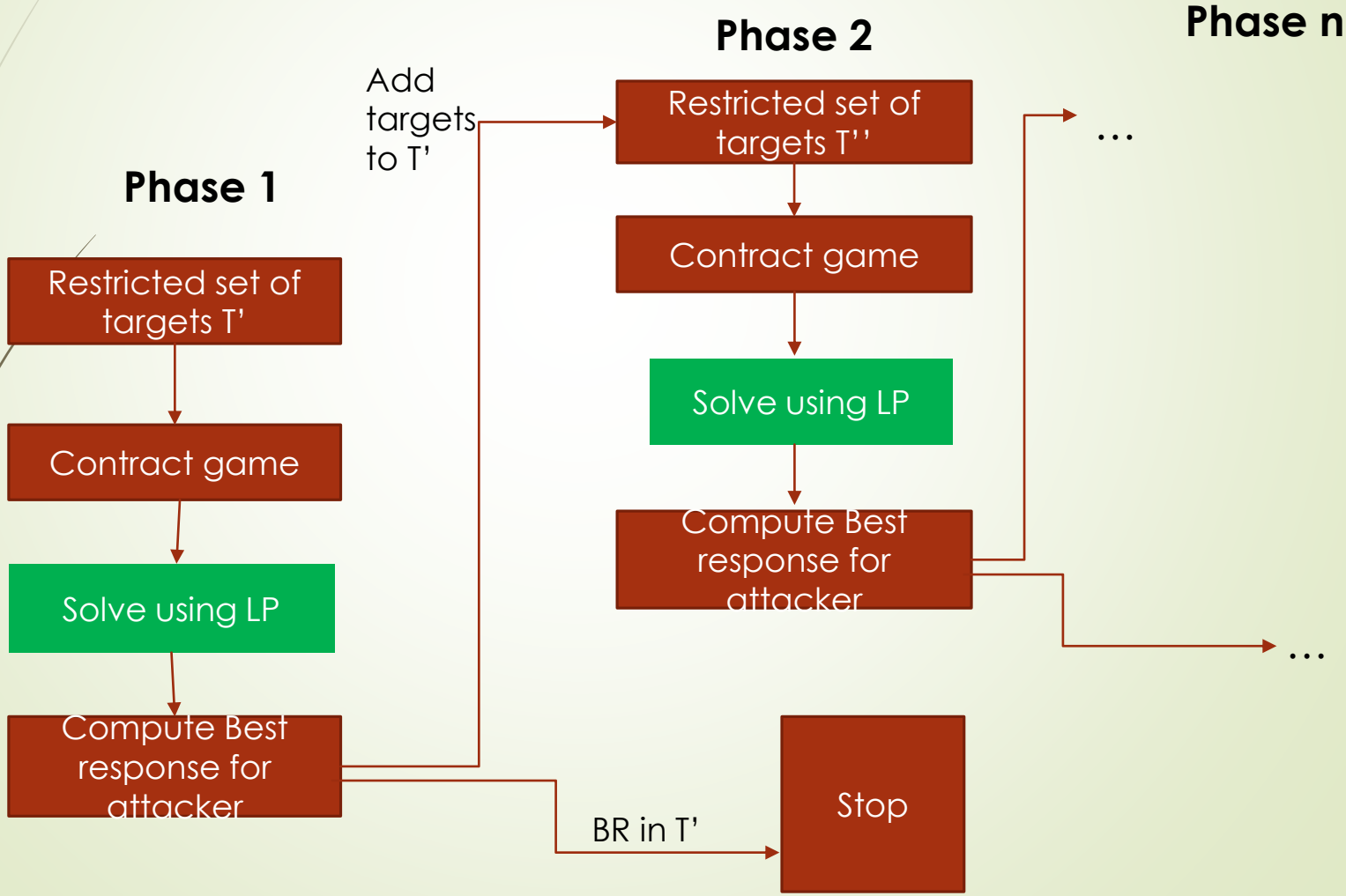
Single Oracle

- Restrict attacker's strategy space
- Incrementally add targets
- Consider full defender strategy space

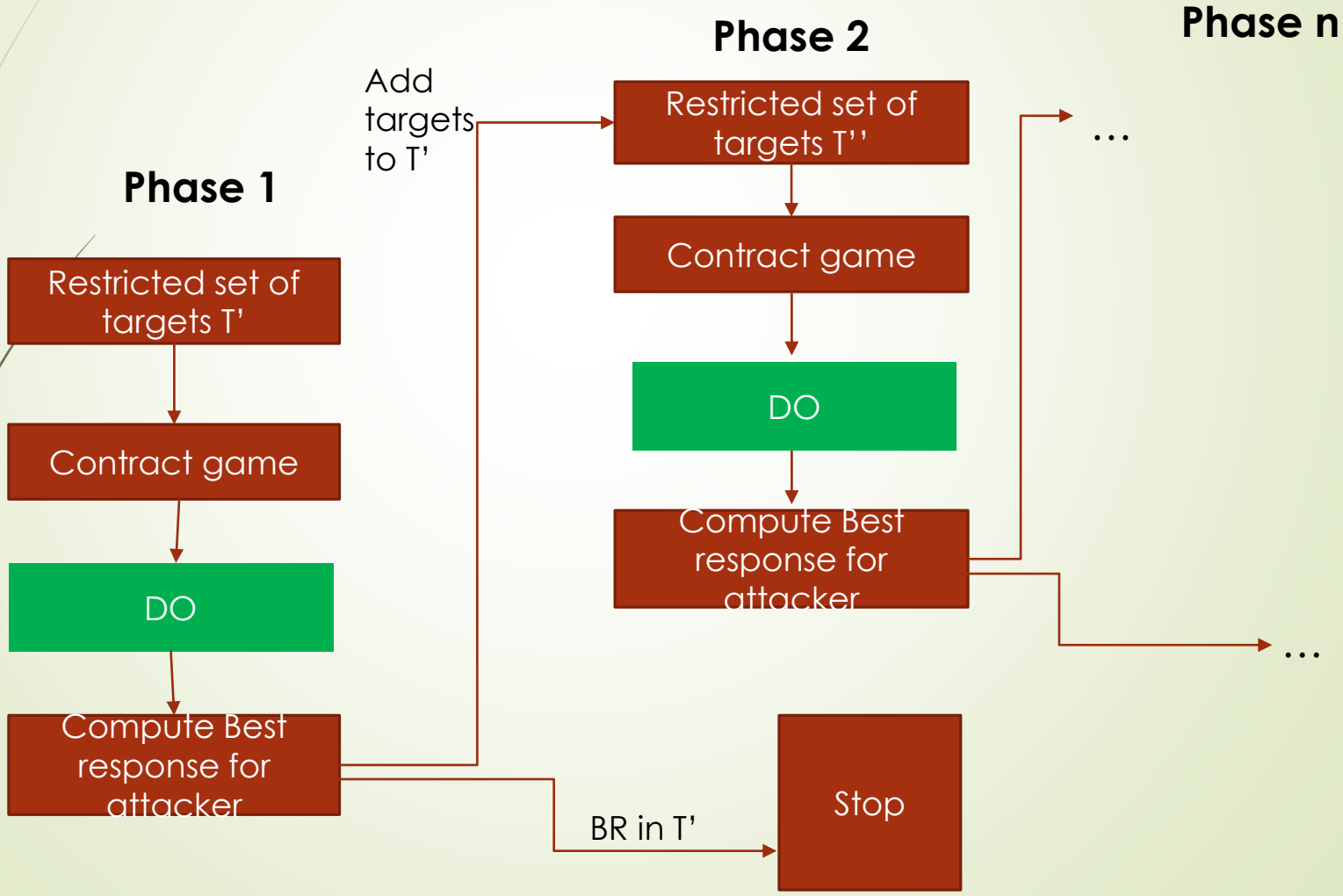
Single Oracle



Single Oracle



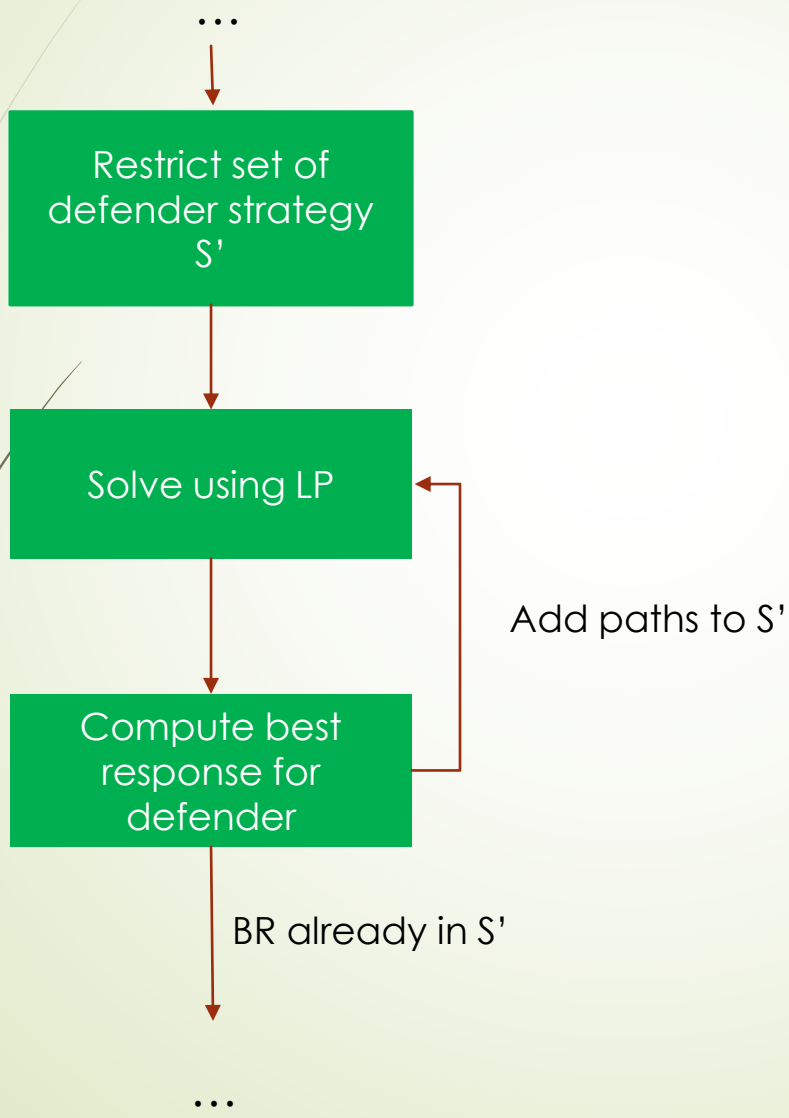
Automated Contraction Using Double Oracle



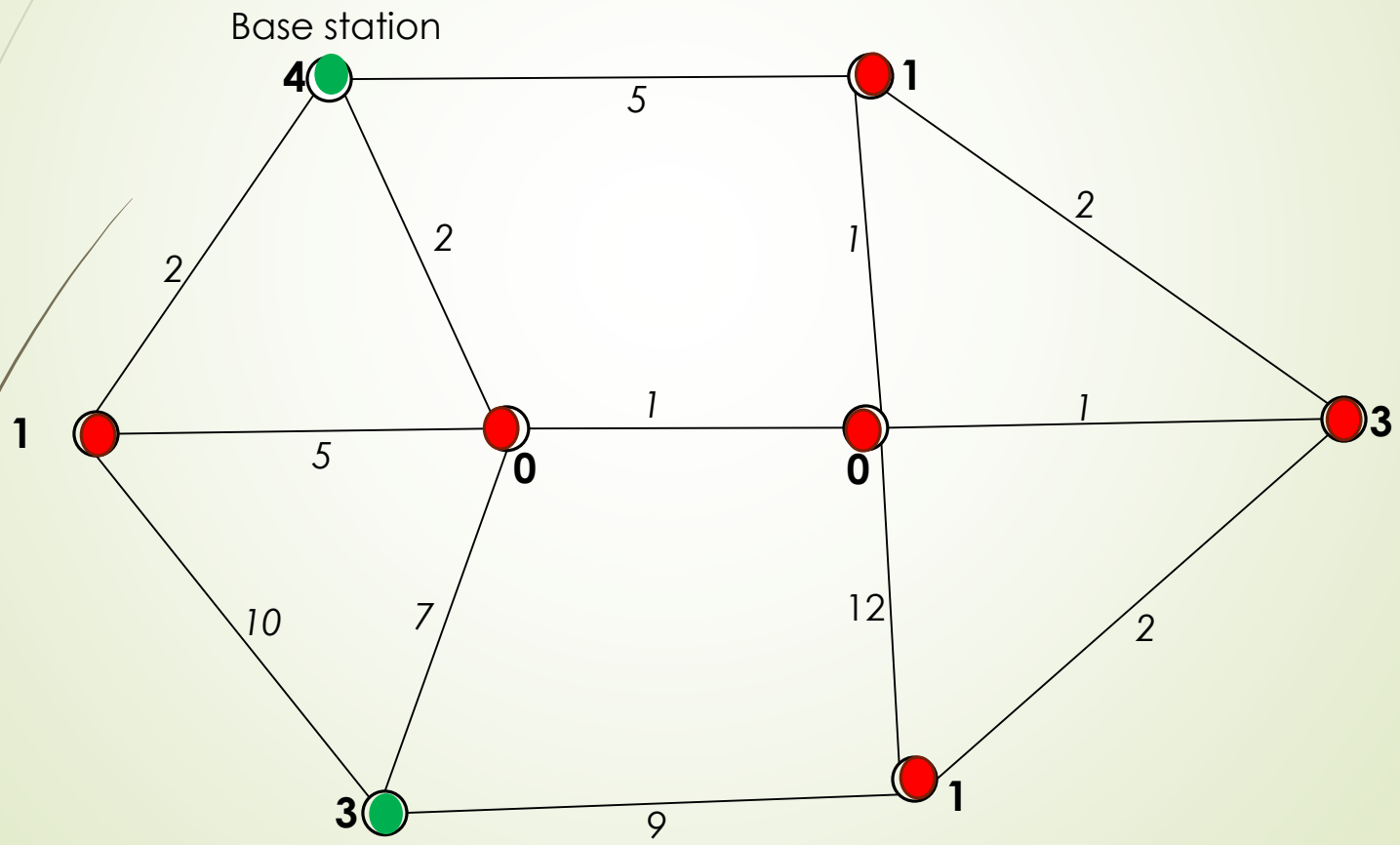
Automated Contraction With Double Oracle

- Restrict attacker's strategy space
- Restrict defender's strategy space

Double Oracle



Single Oracle



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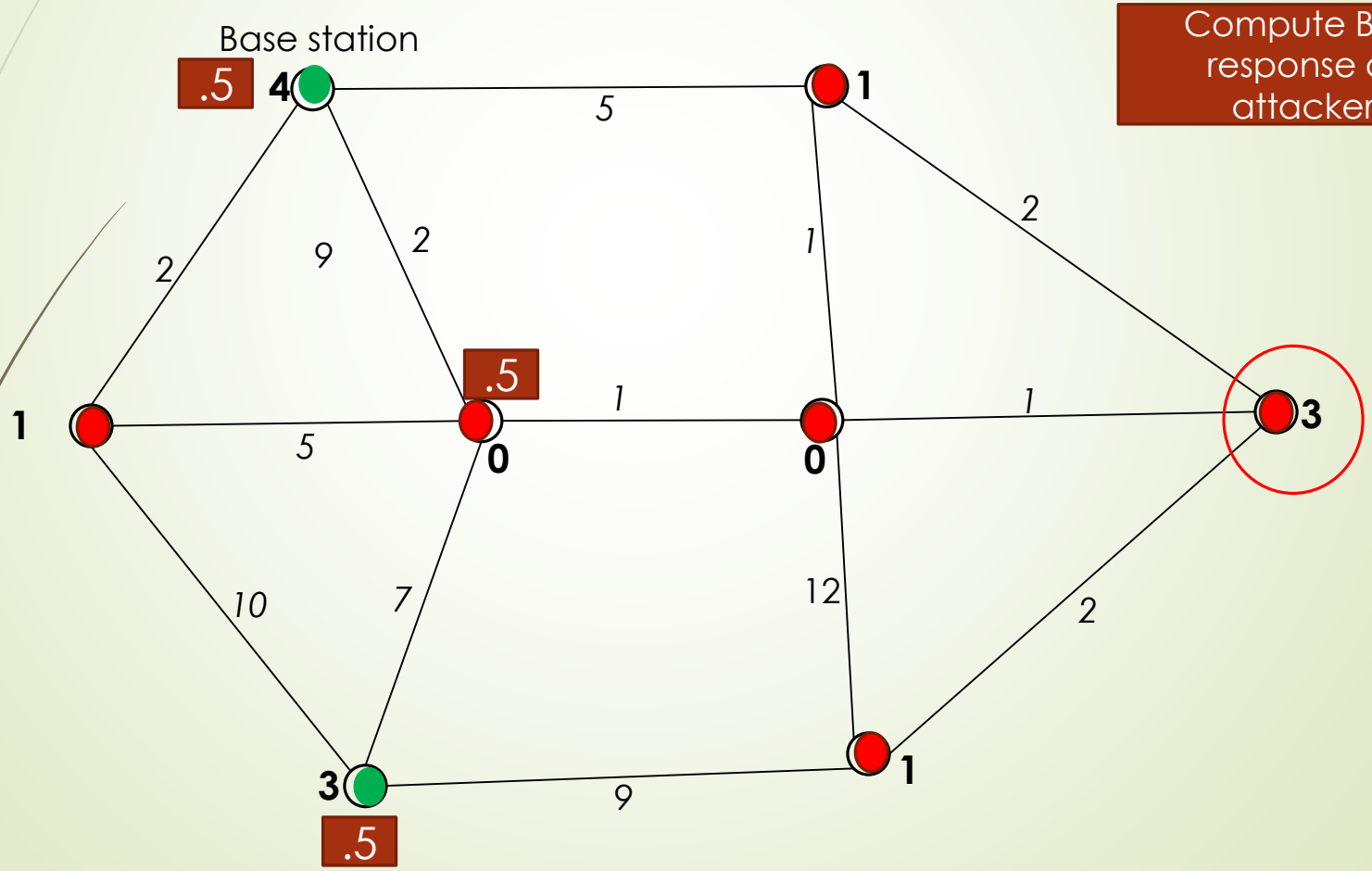

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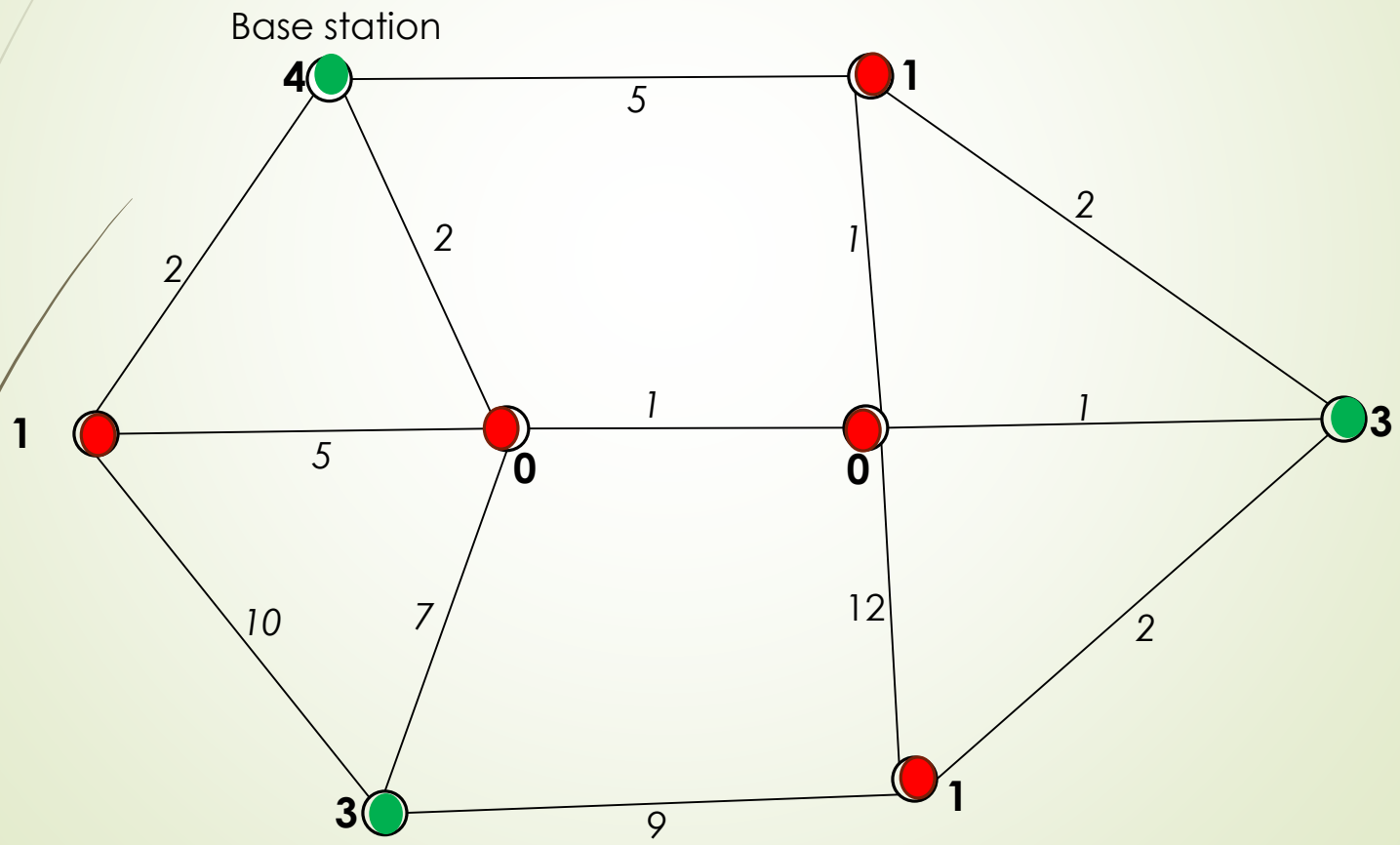

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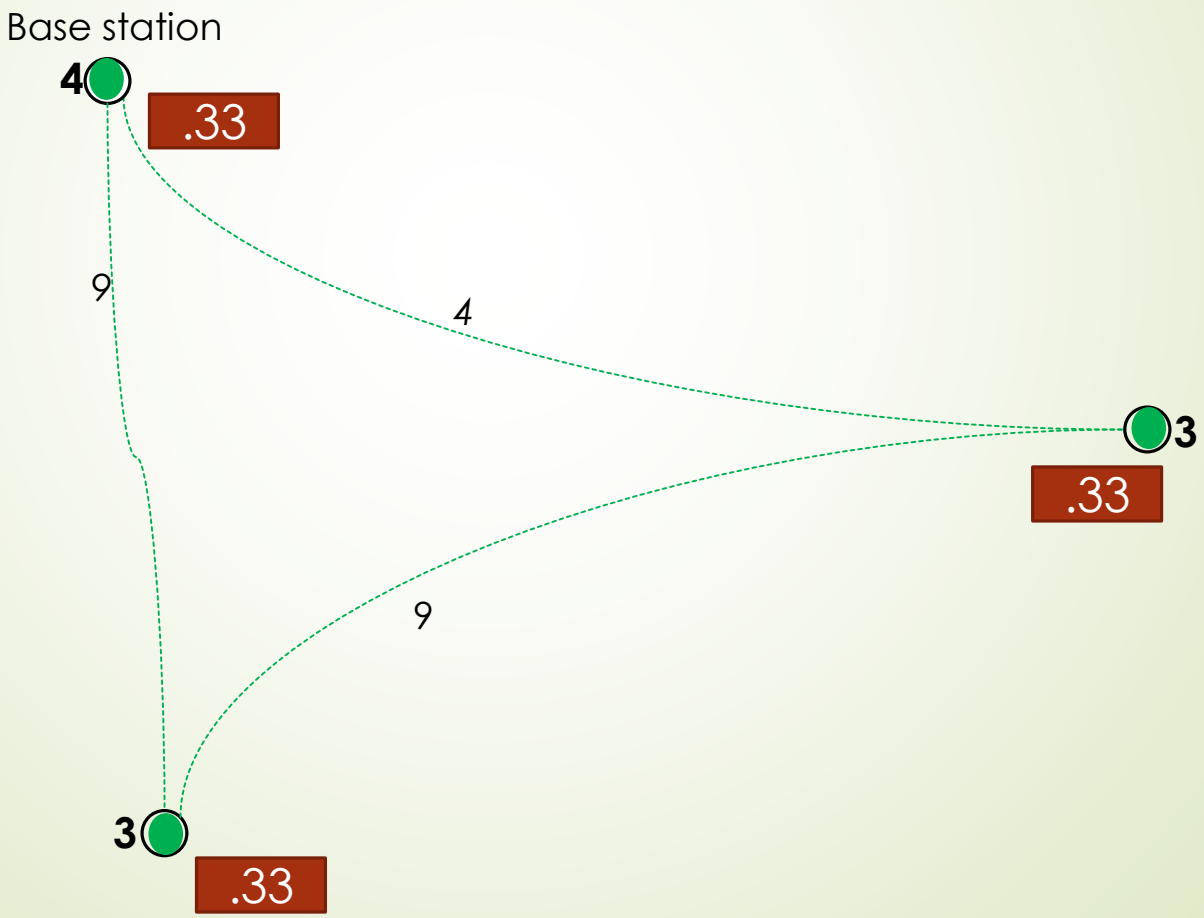
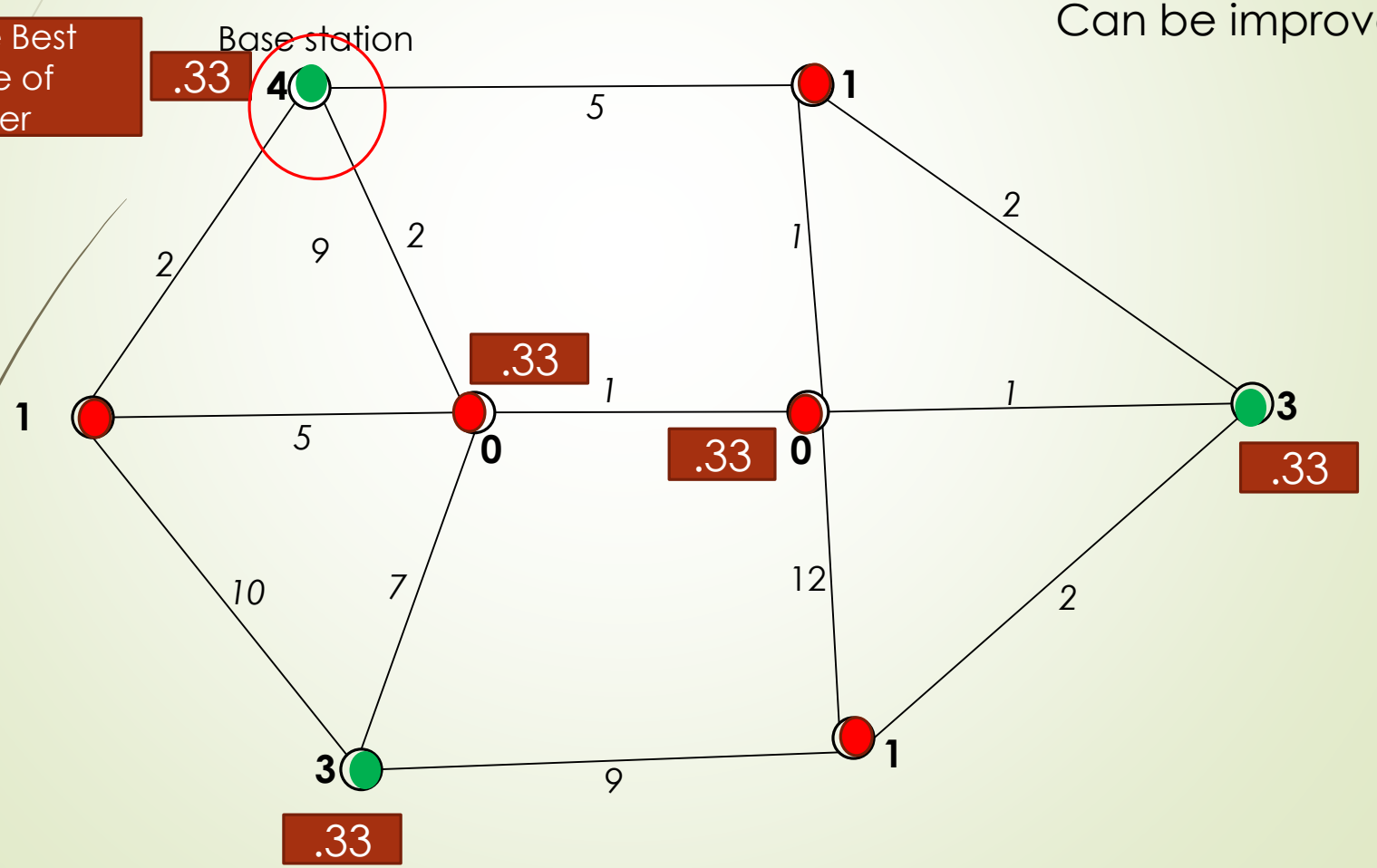


Single Oracle

Compute Best response of attacker

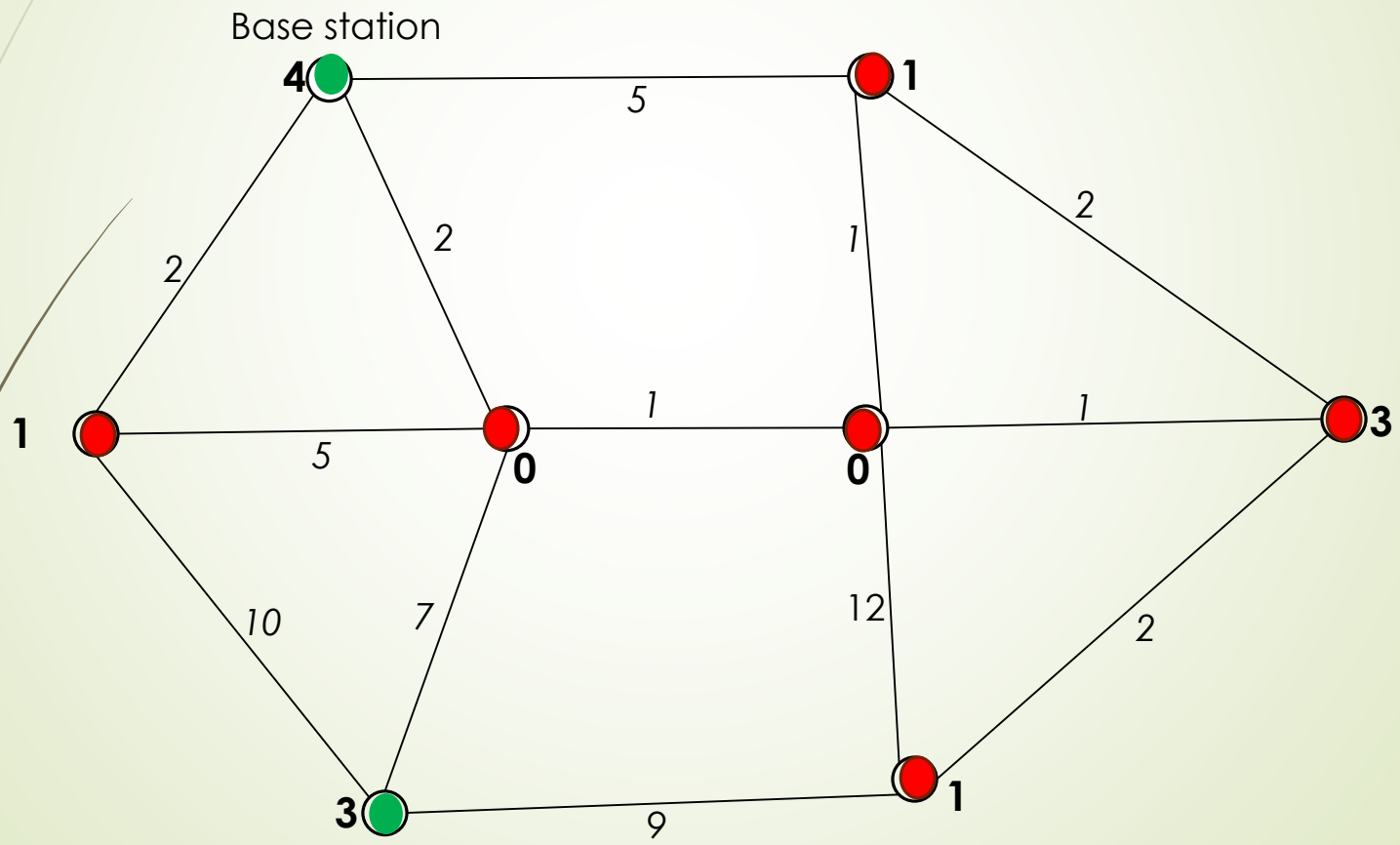


Can be improved

Automated Contraction With Double Oracle

- Restrict attacker's strategy space
- Restrict defender's strategy space

Automated Contraction With Double Oracle



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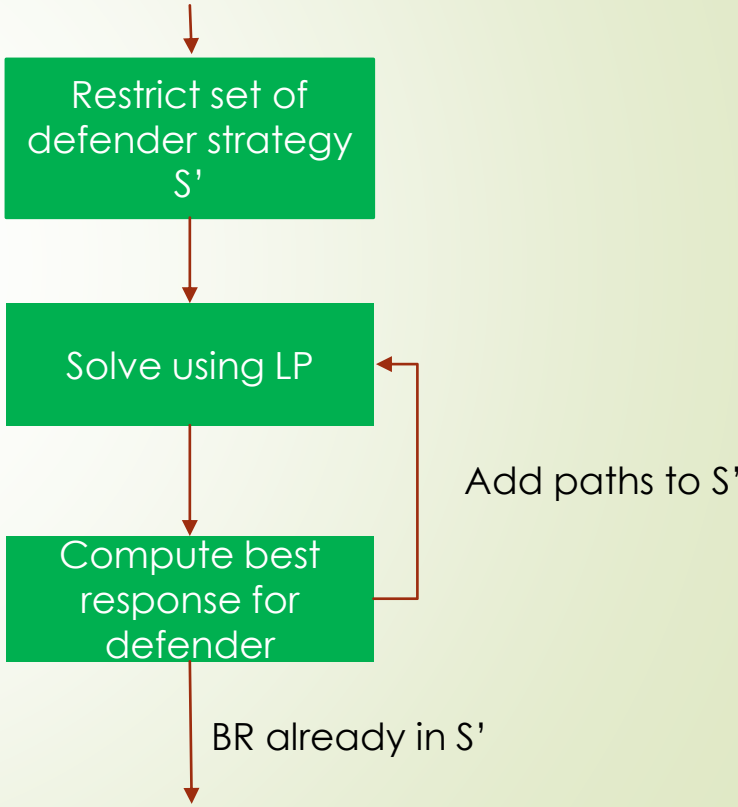

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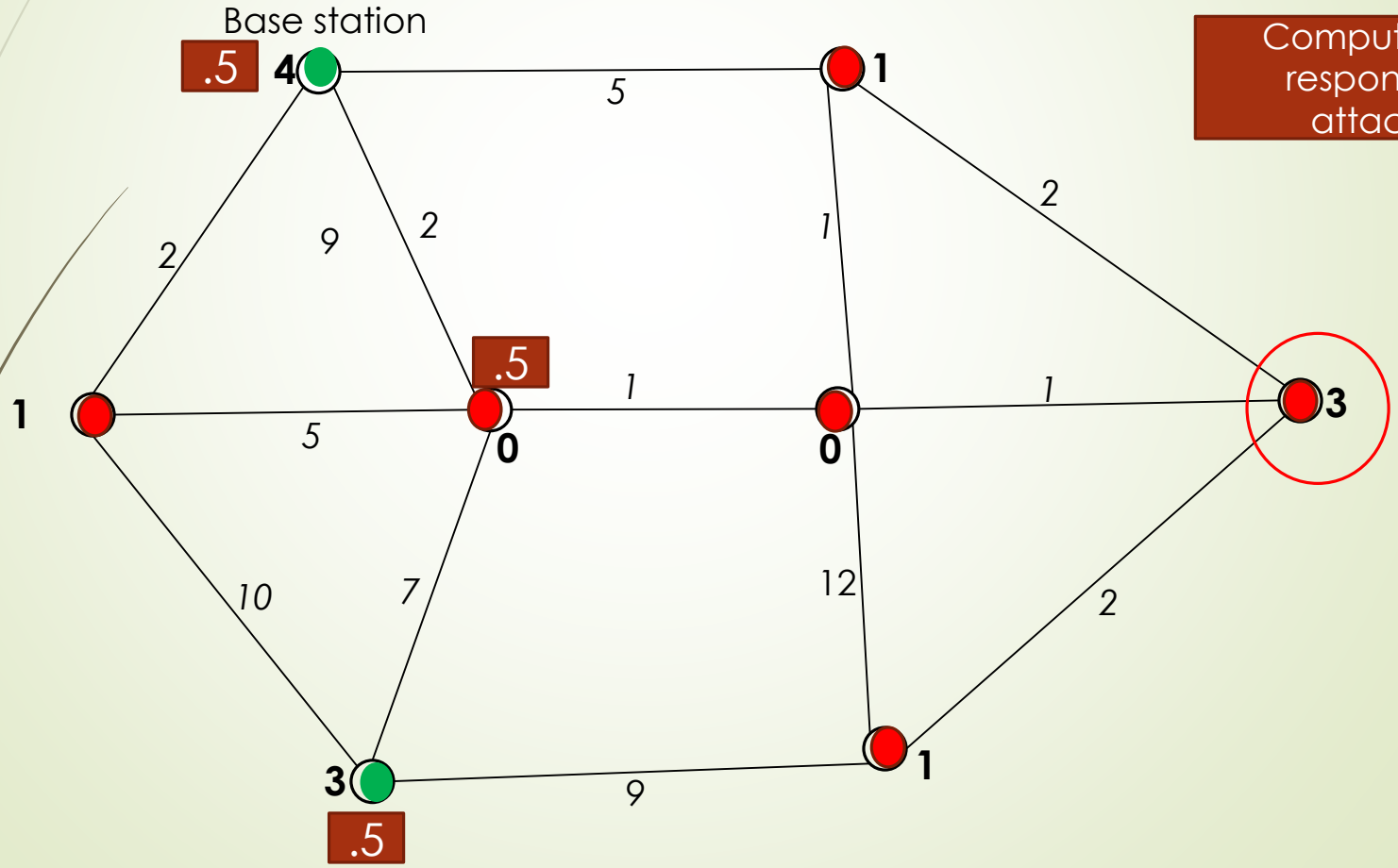

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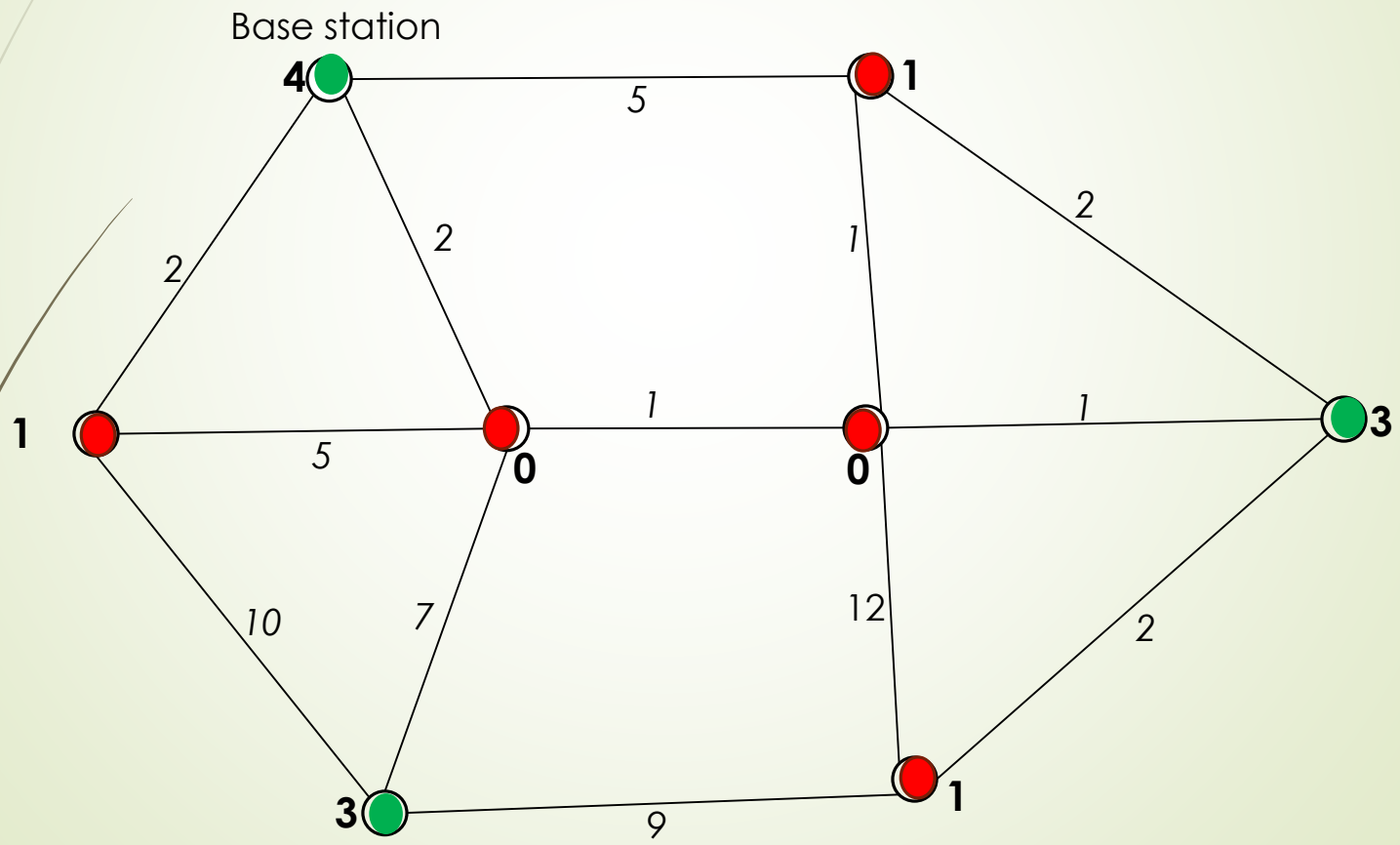

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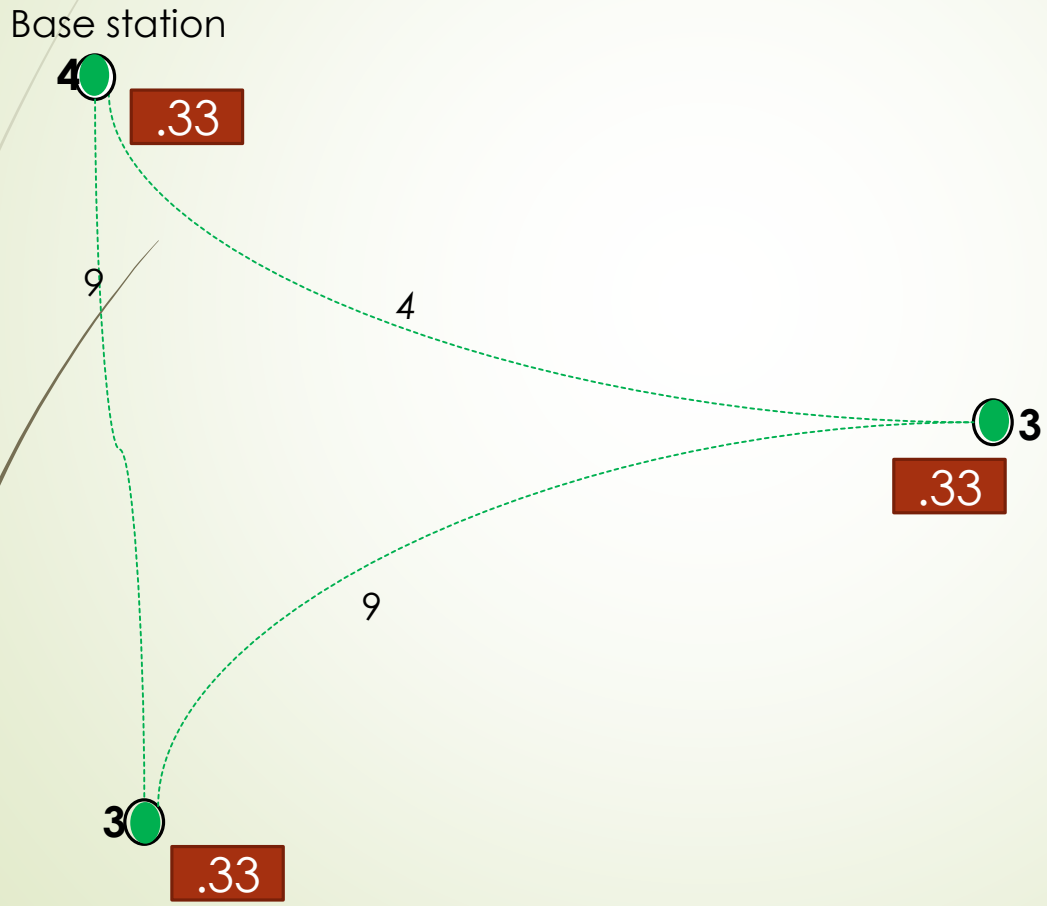

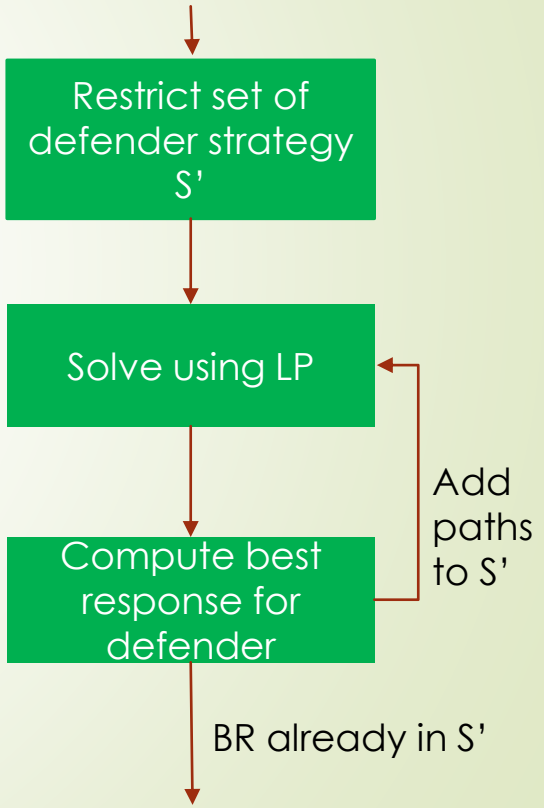

Automated Contraction Using Double Oracle

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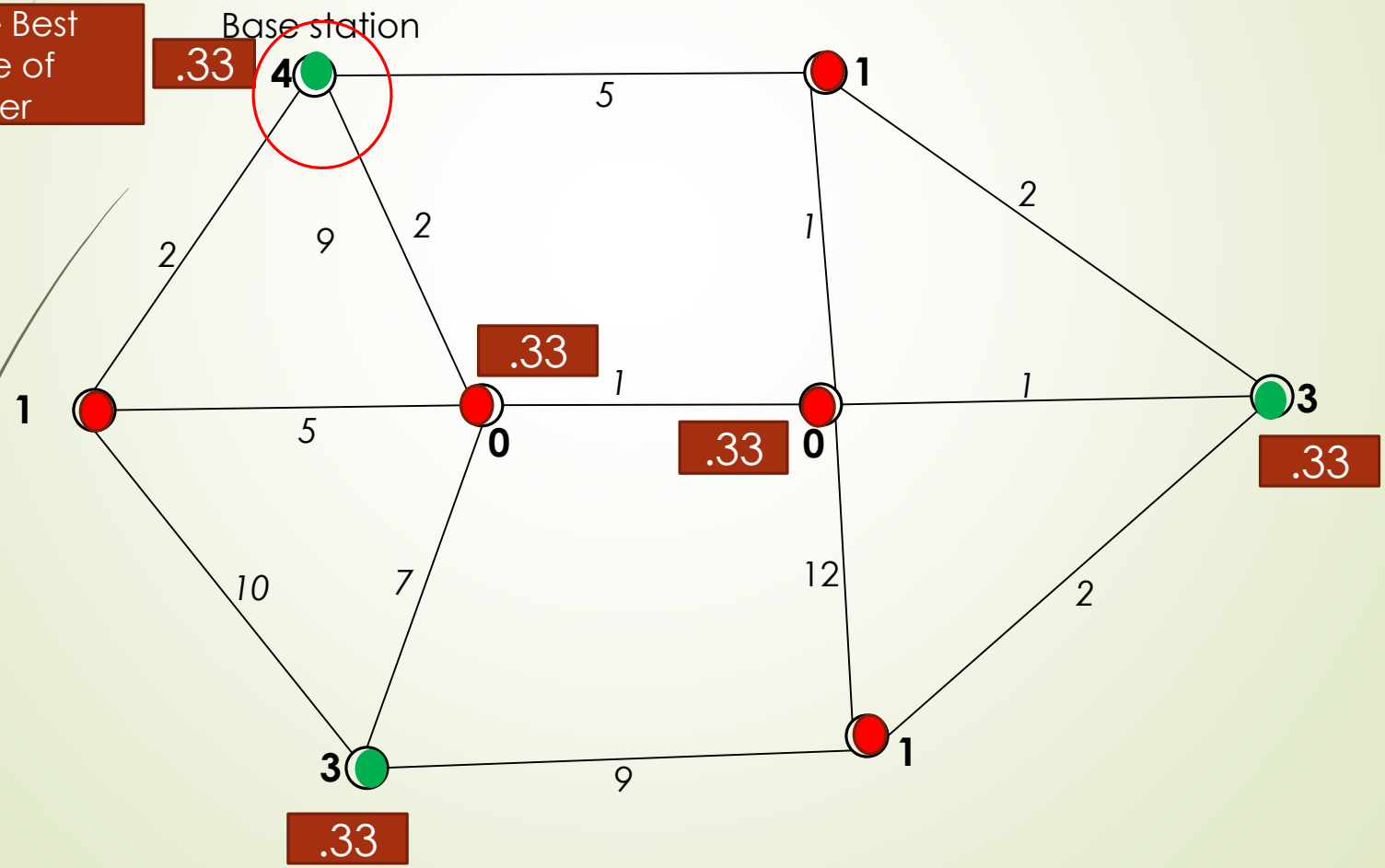
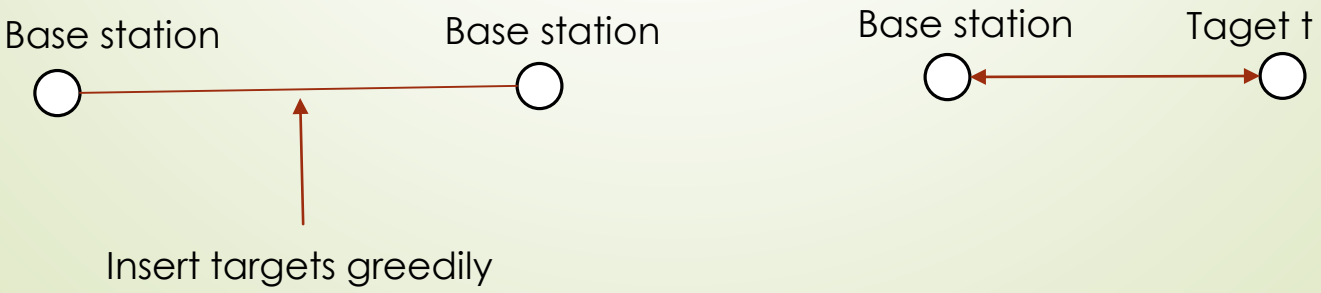


Experiments

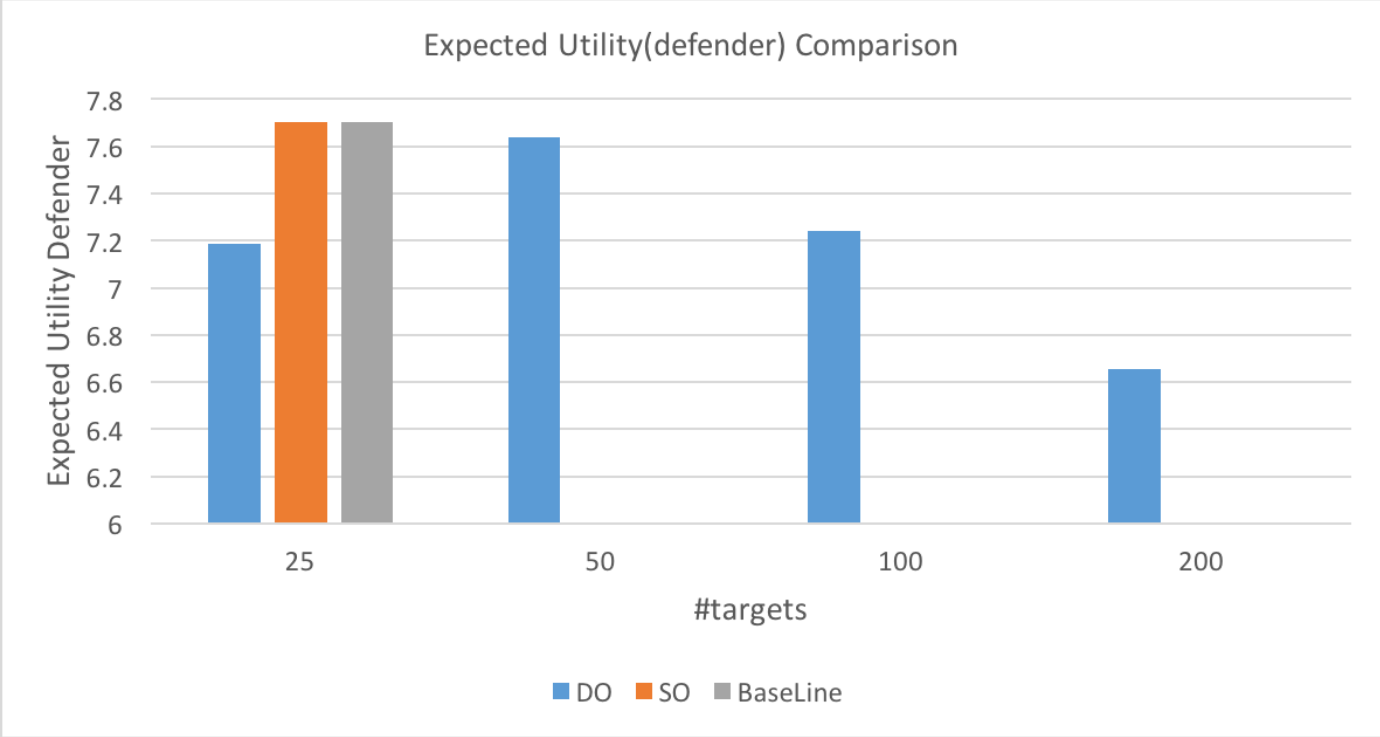
- 20 random 2 player zero-sum games
- size {25, 50, 100, 200}
- Payoffs are randomly chosen from [0, 4] and [8,10] range
- Payoff ranges maintain 90% and 10% frequency respectively.

Heuristics

- For initializing attacker's strategy space and strategy generation:
  - GreedyCover1(GC1)
  - GreedyCoverR(GCR)
- For initializing defender's strategy space:
  - GreedyPath3(GP3)

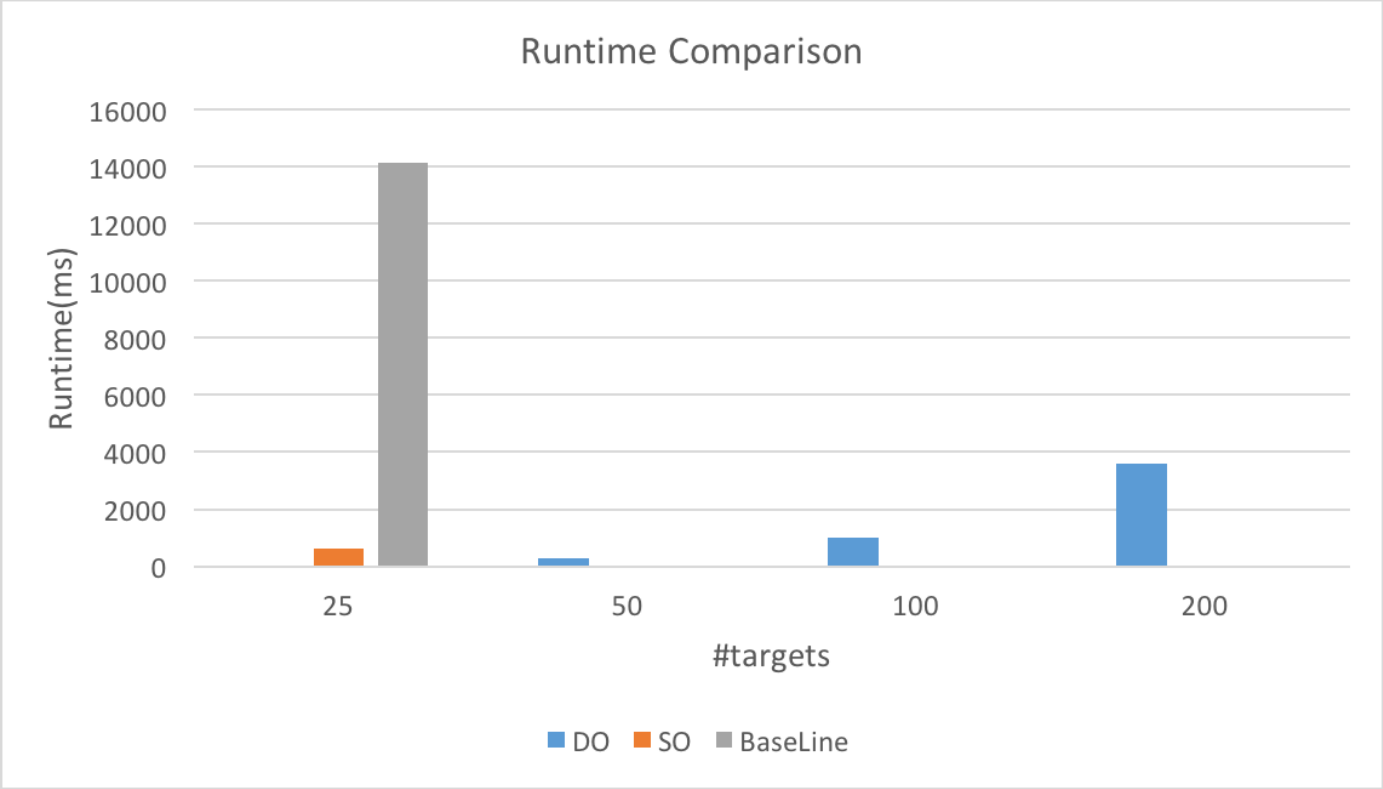


Results



DO = Double Oracle with heuristics
SO = Single Oracle
Baseline = No contraction

Results



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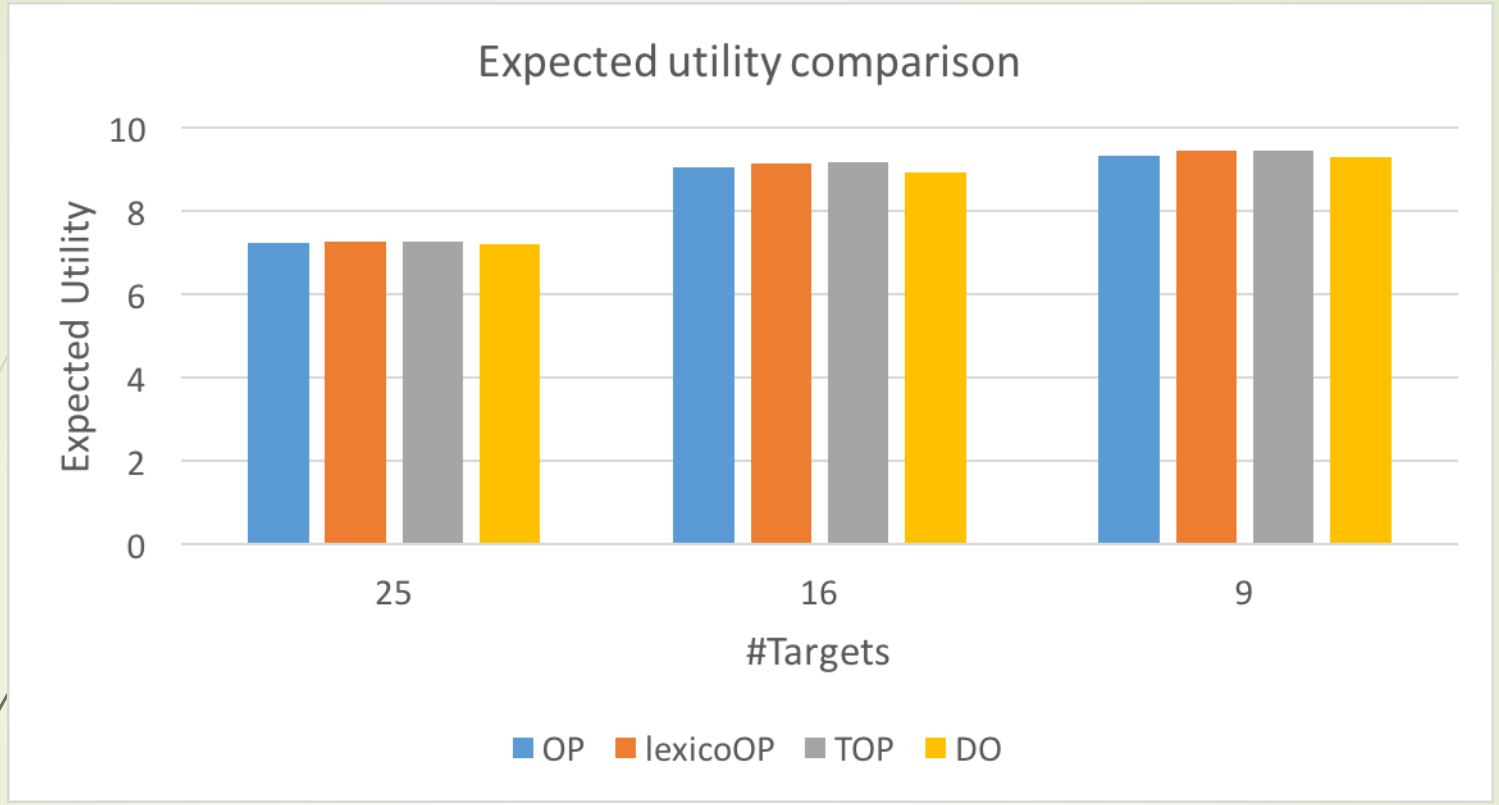
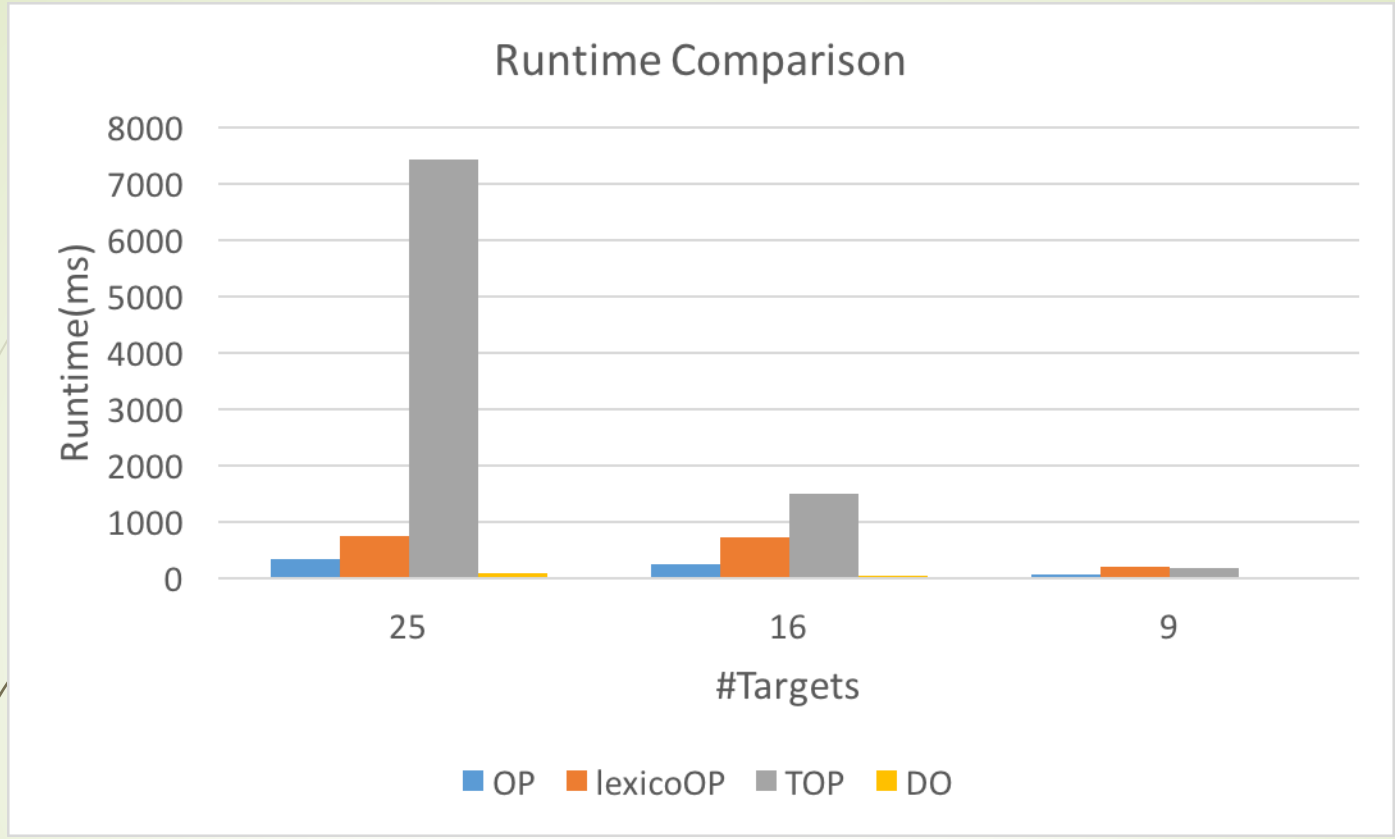


OP = Orienteering Problem

lexicoOP = Lexicographic solution for OP with multiple resources

TOP = Team orienteering problem with multiple visitations

DO = Double Oracle with heuristics



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Conclusion

- First algorithm to combine automated contraction with strategy generation
- Scalable enough to solve GSG having 200 targets within seconds
- Heuristics good and fast enough compared with optimal/sub-optimal solvers

Thanks!