# A GRAPH THEORETIC APPROACH FOR MAXIMIZING TARGET COVERAGE USING MINIMUM DIRECTIONAL SENSORS IN RANDOMLY DEPLOYED WIRELESS SENSOR NETWORKS


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# INTRODUCTION

# INTRODUCTION

- A system consisting of wireless sensors and targets.
- Both deployed randomly and static.

2 types of sensors:

- Isotropic
  Circular coverage
- Directional (within the scope of this thesis)
  Coverage in a particular direction
  example: camera

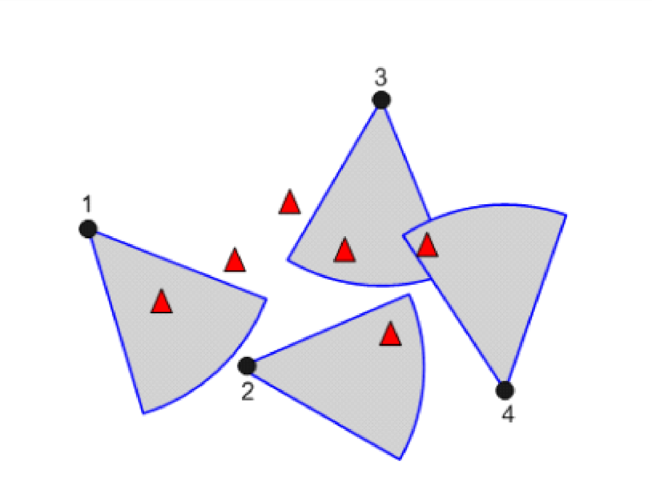
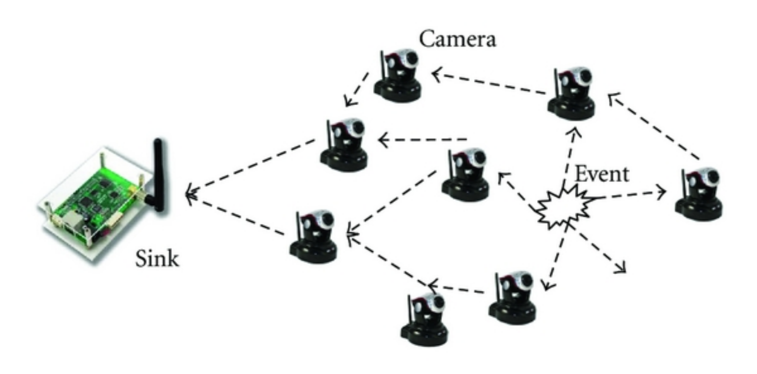


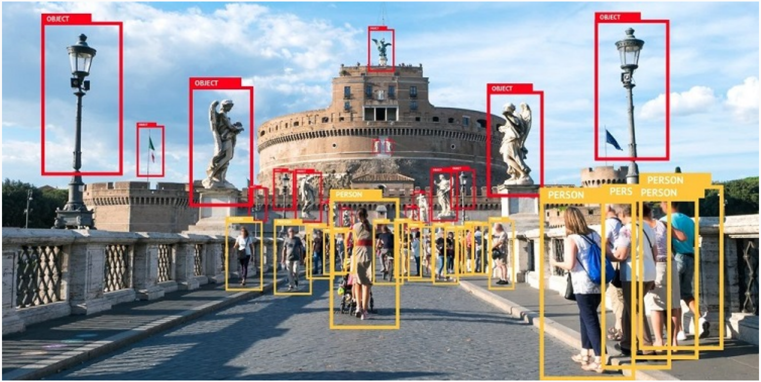

**Figure:** A random deployment scenario

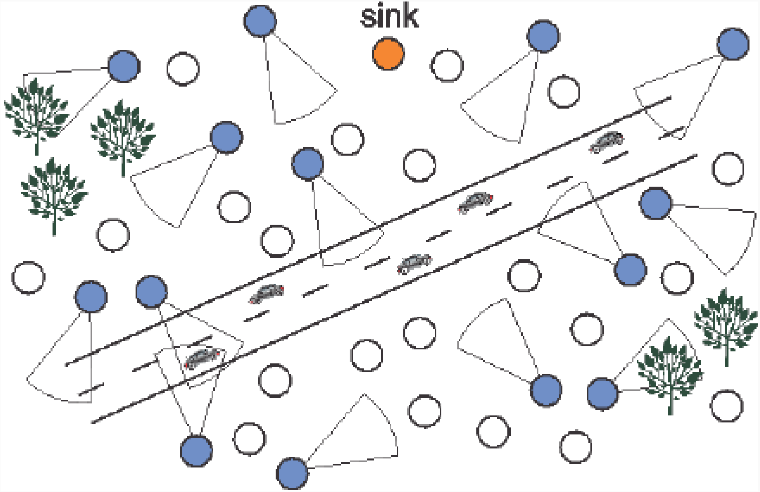
# APPLICATIONS

# APPLICATION: SURVEILLANCE



# APPLICATION: OBJECT TRACKING

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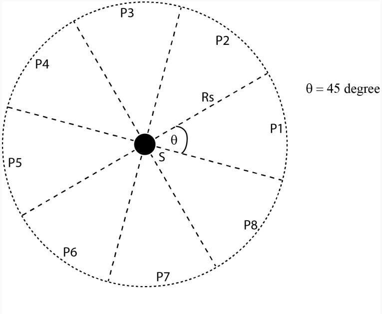
# BACKGROUND

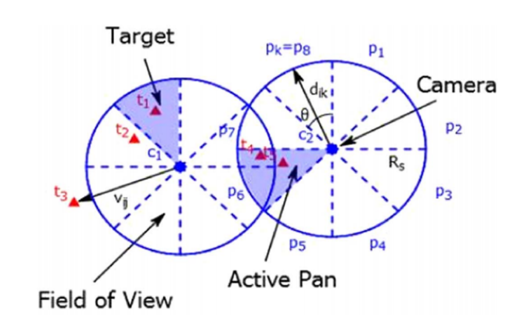
- FOV(Field of View):
  It is the sensing region of a sensor/extent of sensing region which can be captured at any direction.
- Used sensors:
  Pan-tilt-zoom cameras
- Our assumptions:
  Pan-only Cameras

- Parameters:
  - Range ($R_s$)
  - Angle ($\theta$)




- Assumptions:
  We will consider homogeneous cameras (the parameters will be same for all cameras).

- **TIS test:** This means target in sector (pan) test.




- **Formula:** $\phi_{ij} = \cos^{-1}\left(\frac{\vec{d_{ij}}.\vec{v_{ij}}}{|\vec{d_{ij}}||\vec{v_{ij}}|}\right)$

  i $\phi_{ij} \leq \frac{\theta}{2}$

  ii $|\vec{v_{ij}}| \leq R_s$

- 2 classes of deployment on the basis of the ratio between the number of directional sensors and targets:
    i **Under Provisioned System:**
      No point of minimization of active sensors.
    ii **Over Provisioned System (within the scope of this thesis)**
      Minimization of active sensors is an important aspect.

# PROBLEM FORMULATION

# OBJECTIVES

- Maximization of target coverage
- Minimization of active sensors

- It is an NP-hard problem.
- Formulate different heuristics to achieve a near optimal solution better than the existing one's.

# LITERATURE REVIEW

# LITERATURE REVIEW

| Work | Principle | Description | Comments |
|---|---|---|---|
| Ai and Abouzeid 2006 | • Sensor-oriented<br>• Greedy Heuristic | • Integer Linear Programming (ILP)<br>• Centralized Greedy Algorithm (CGA)<br>• Distributed Greedy Algorithm (DGA) | • Poor performance in over-provisioned system<br>• ILP is not scalable to solve large scale scenario<br>• CGA and DGA fail to resolve tie between sensors |

# LITERATURE REVIEW

| Work | Principle | Description | Comments |
|---|---|---|---|
| Munishwar and Abu-Ghazaleh 2013 | • Sensor-oriented<br>• Modified Greedy Heuristic | • Centralized Force-directed Algorithm (CFA):<br>Priority is given to the sensors covering targets in a single pan. | • Poor performance in over-provisioned system<br>• Fails to minimize the number of active sensors |

# LITERATURE REVIEW

| Work | Principle | Description | Comments |
|---|---|---|---|
| Munishwar et al. 2011 | • Sensor-oriented<br>• Communication between sensors | • Distributed Force-directed Algorithm (DFA):<br>• Each sensor assigns a unique priority<br>• Area based or target based approach<br>• Each sensor orients itself towards maximal coverage pan.<br>• This orientation information exchanged among sensors.<br>• If overlapping coverage found, higher priority sensor prevails. | • Fails to minimize the number of active sensors |

# LITERATURE REVIEW

| Work | Principle | Description | Comments |
| --- | --- | --- | --- |
| H. Zannat et al. 2016 | • Target-oriented | • Greedy Target Oriented Heuristic (GTOH)<br>• Pure Target Oriented Heuristic (PTOH)<br>• Hybrid Target Oriented Heuristic (HTOH) | • Fails to minimize the number of active sensors. |

# LITERATURE REVIEW

| Work | Principle | Description | Comments |
| --- | --- | --- | --- |
| Fusco and Gupta 2009 | • k-coverage problem | • Centralized Greedy Algorithm:<br>Assumption: Each sensor has overlapping pans instead of discrete pans. | • Huge variation among targets in achieving the desired k-coverage. |
| | • Some approximation algorithms related to directional sensors | • orient all the given sensors in order to maximize coverage<br>• place and orient a minimum number of sensors in order to cover the given area<br>• place and orient the given number of sensors to maximize the area covered | |

# LITERATURE REVIEW

| Work | Principle | Description | Comments |
|---|---|---|---|
| Malek et al. 2016 | • Balanced k-coverage problem | • Improved the k-coverage solution proposed by Fusco and Gupta (2009) to achieve balanced k-coverage. | • Reduced the number of uncovered targets as well as providing k-coverage to targets as much as possible |

# MOTIVATION

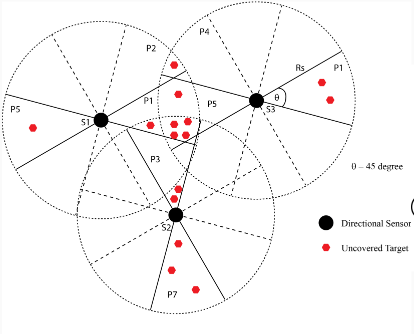
- All the heuristics are formulated based on greedy approach.
- Either sensor-oriented or target-oriented.
- In all the works, selection of a sensor and fixing its orientation are merged into a single step.
- Failure to remove the covered targets at each iteration efficiently
- Most of them fail to achieve active sensor minimization, only focusing on coverage maximization.
- k-coverage problems address fault tolerance issue, we limit ourselves only to 1-coverage.

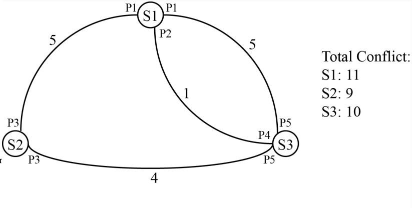
# CONTRIBUTION

- Fusing both Sensor-oriented and Target-oriented approach.
- Splitting the step of selection of sensor and orientation
- Model the problem in graph theoretic approach
- Developing an efficient way of removing covered targets at each iteration
- Reducing the run-time without compromising the performance

# METHODOLOGY

- **Nodes:** Sensors (Cameras).
- **Edges**
  Conflict of targets.



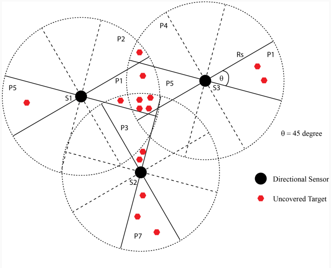

Model a weighted multi-graph.
We can define it as conflict graph.

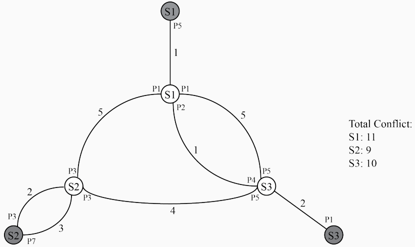
- Different heuristics
  - Total maximum conflicts of the nodes
  - Total minimum conflicts of the nodes

- Greedy approach
    - That orientation which will cover the total maximum number of targets
- We can also choose the orientation with the maximum/minimum conflict

# ACHIEVING TARGET-ORIENTED NATURE

- **Shadow edge:** There will be self-edges for each node keeping the number of non-conflicted targets for each orientation.




- Actually without looking at the targets, we can get the total knowledge of lonely targets and conflicted targets.

- **In greedy-approach,** when a sensor and its orientation is selected the targets covered by that orientation of the sensor should be removed from the sensors which also cover those targets. For this task, whole set of remaining sensors should be checked.
- **In our model,** the task become localized. When we select a sensor, we know the sensors with which the sensor has conflict.

# TIME COMPLEXITY

- The localized search will reduce the run time than the greedy one.

# COMPARISON OF DIFFERENT HEURISTICS

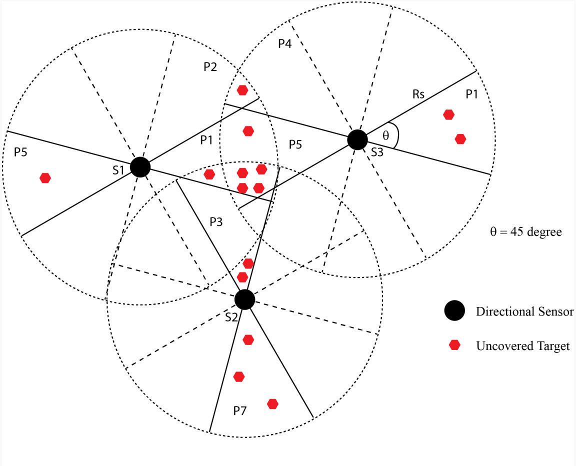



**Figure:** An example scenario

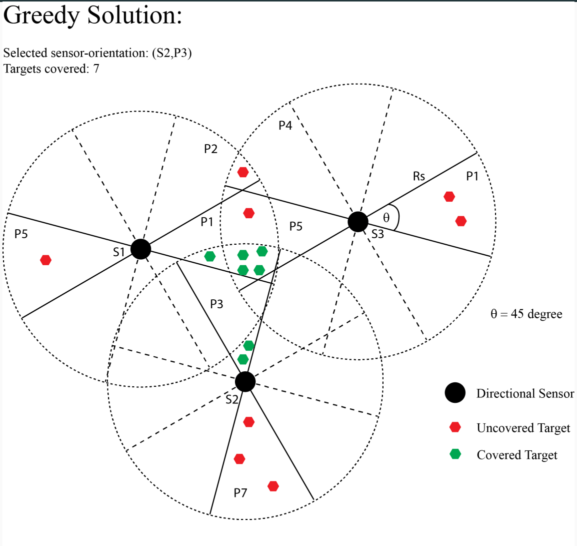



**Figure:** Greedy Step 01

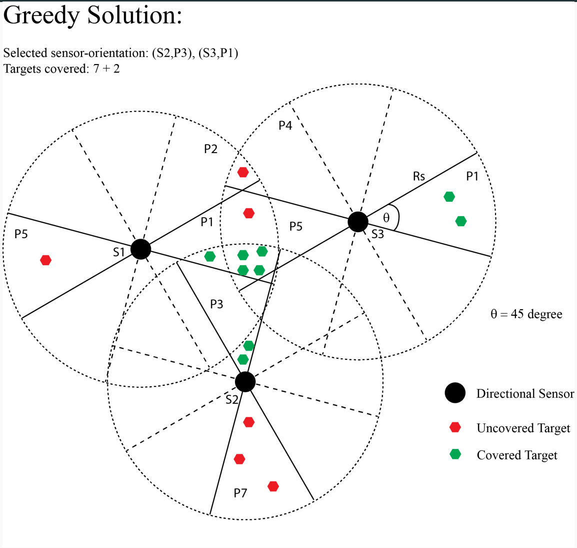



**Figure:** Greedy Step 02

# COMPARISON OF DIFFERENT HEURISTICS

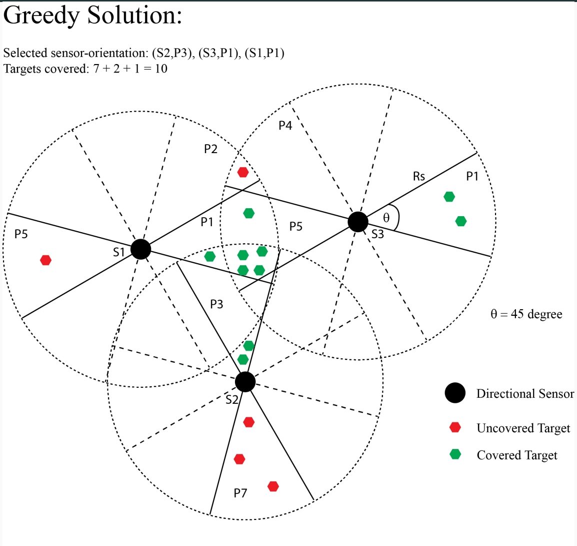



**Figure:** Greedy Step 03

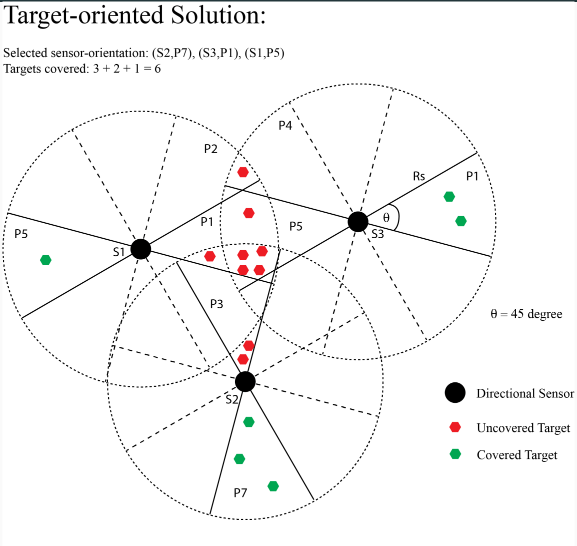
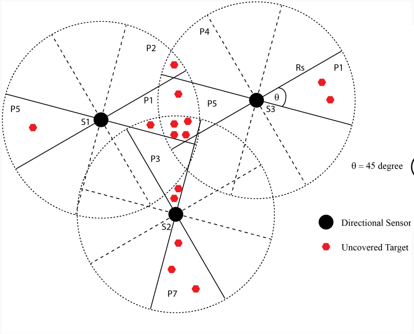



**Figure:** Target-oriented approach



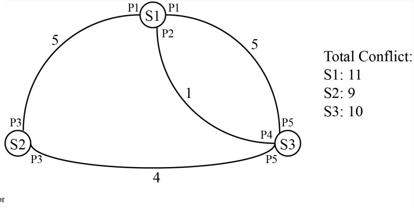




Figure: Modeling conflict graph

# COMPARISON OF DIFFERENT HEURISTICS

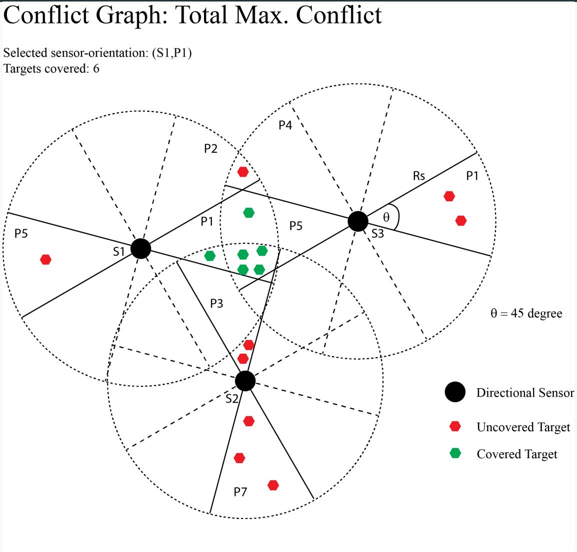



**Figure:** Conflict graph approach step 01

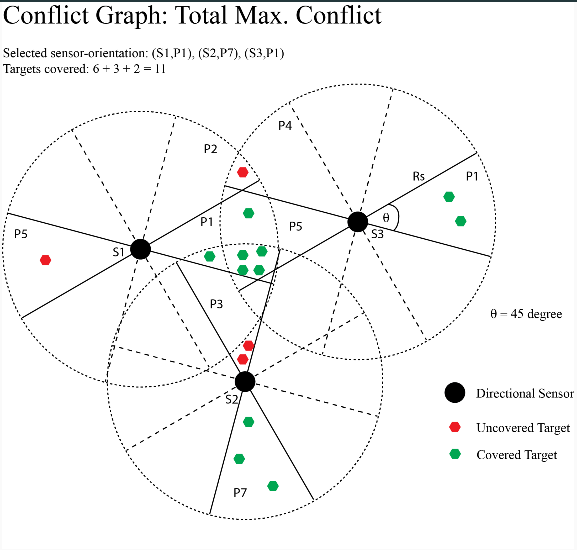



Figure: Conflict graph approach step 02 and 03

# COMPARISON OF DIFFERENT HEURISTICS

| Heuristics | Coverage (out of 15 targets) |
|---|---|
| Greedy | 10 |
| Target-oriented | 6 |
| Conflict graph | 11 |

# RESULTS

There are three performance metrics used:

- Coverage Ratio (CR)
- Ratio of Active Sensors (RAS)
- Target Coverage Per Sensor (TCPS)

There are four heuristics whose performances are evaluated and compared:

- Centralized Greedy Algorithm (CGA) [Ai and Abouzeid, 2006]
- Total Max Conflict Heuristics (TMxCH)
- Total Min Conflict Heuristics (TMnCH)
- TMxCH with Shadow Edge (TMxCHSE)

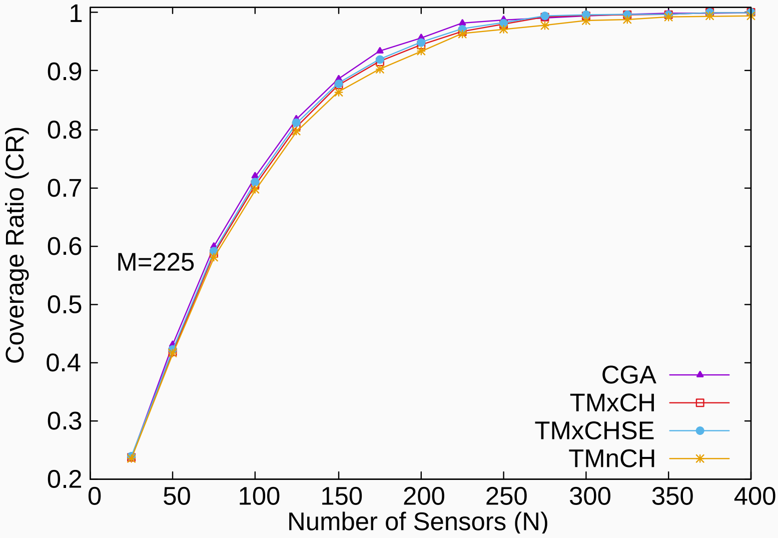



**Figure:** Coverage Ratio (CR) varying sensors with fixed targets (M)

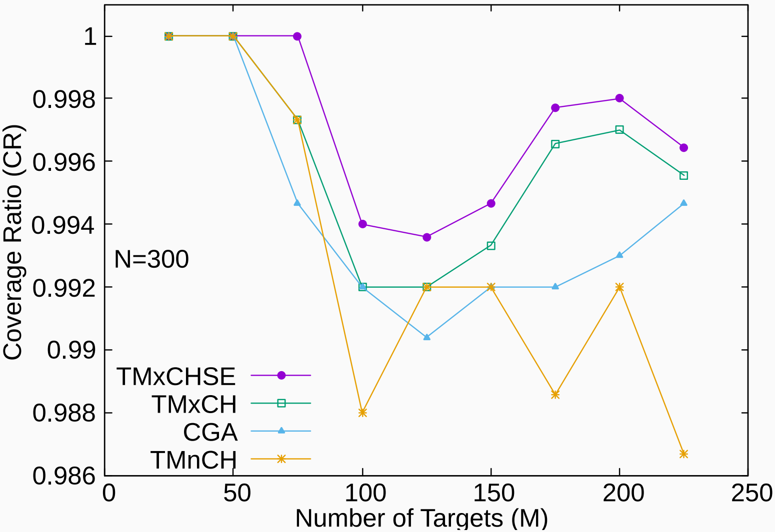



Figure: Coverage Ratio (CR) varying targets with fixed sensors (N)

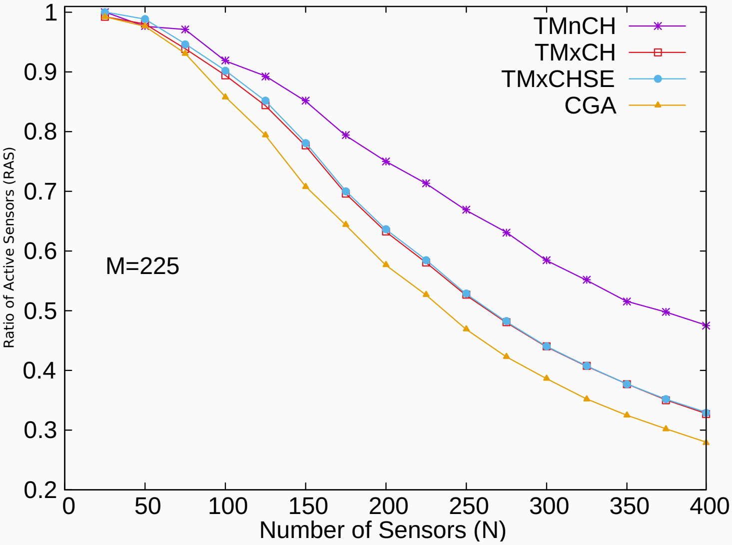



**Figure:** Ratio of Active Sensors (RAS) varying sensors with fixed targets (M)

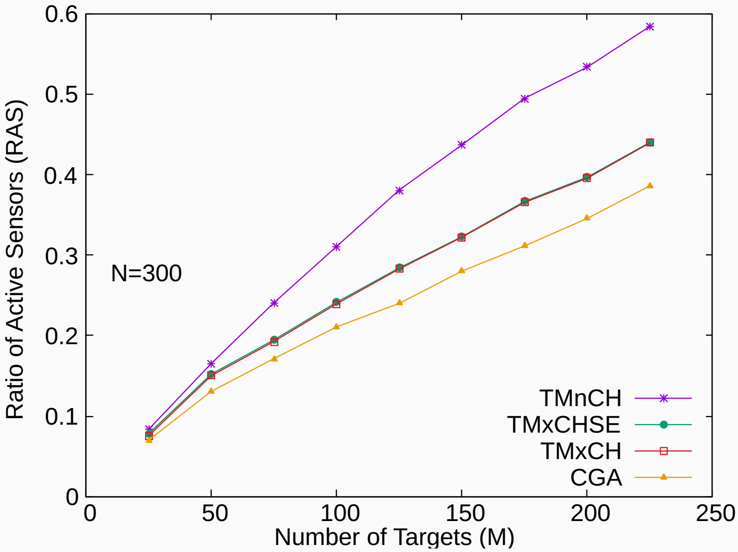



Figure: Ratio of Active Sensors (RAS) varying targets with fixed sensors (N)

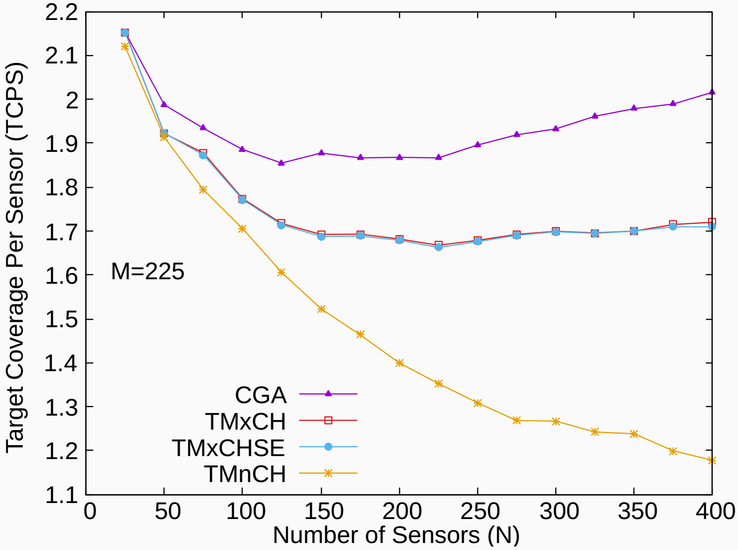



**Figure:** Target Coverage Per Sensor(TCPS) varying sensors with fixed targets

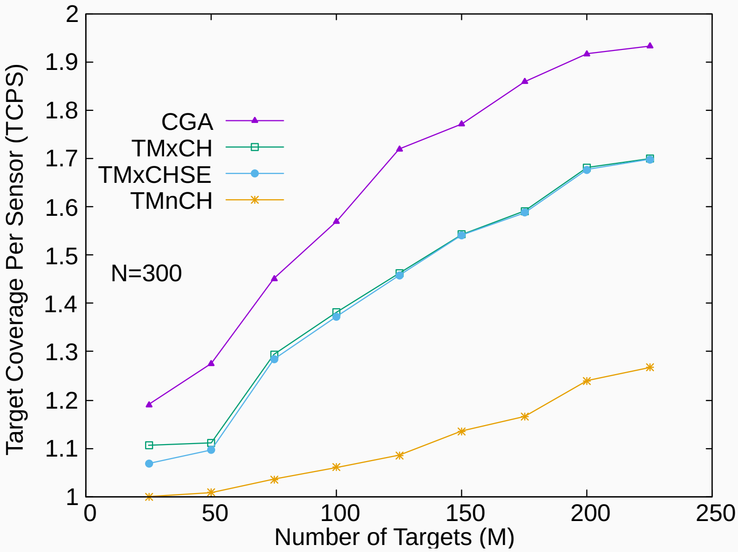



Figure: Target Coverage Per Sensor(TCPS) varying targets with fixed sensors

Hardware and Software specifications of the machine used for simulation:

- Hardware
    - CPU: core i5-7th Generation
    - RAM: 8GB DDR4
- Software
    - OS: windows10
    - Environment: JDK 8.0

# RUN-TIME COMPARISON

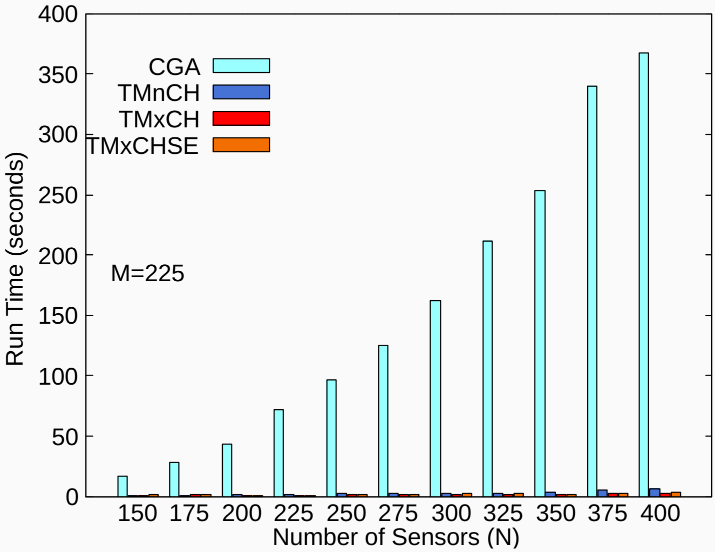



Figure: Run-time comparison varying sensors with fixed targets

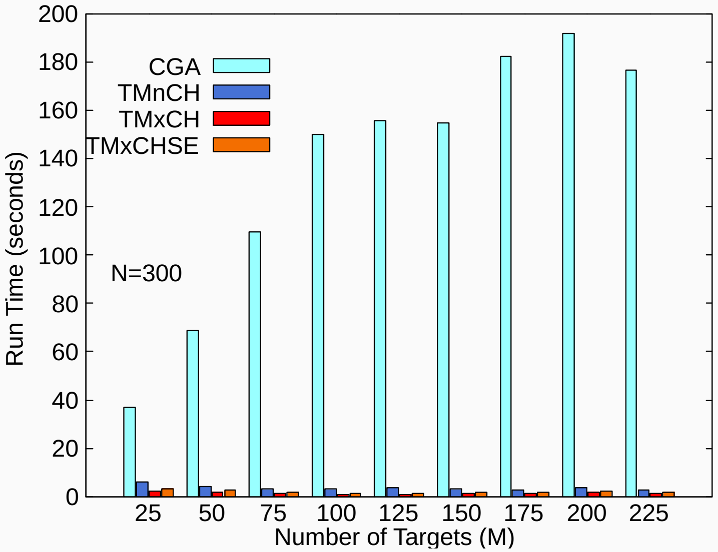



**Figure:** Run-time comparison varying targets with fixed sensors

# CONCLUSION

- We have modeled the conflict-graph which enabled to attack the problem in a graph theoretic approach.
- We have formulated 3 different heuristics suitable for applying to our graph model.
- We have reduced the run-time effectively without compromising the performance.

- This graph model can be applied to solve:
  - k-coverage problem
  - balanced k-coverage problem
  - heterogeneous k-coverage problem
- Many more heuristics can be developed which are suitable for applying to this graph model related to aforesaid problem domains.
- This can be applied to sensors with orientations in other dimensions (like tilt and zoom)

- Add new dimension to look at the problem and generate corresponding solution.
- Graph approach will open new doors to explore the problem space for finding better solutions.
- We can apply different heuristics to our graph modeling which tremendously improve the run-time.

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# Thank You!

# Questions?