Overview: Chapter 4 (cont)

- Fidelity and Yield in a Volcano Monitoring Sensor Network
  - Geoff Werner-Allen, Konrad Lorincz, Jeff Johnson, Jonathan Lees and Matt Welsh
- VigilNet: An Integrated Sensor Network System for Energy-Efficient Surveillance
  - TIAN HE , SUDHA KRISHNAMURTHY, LIQIAN LUO, TING YAN, LIN GU, RADU STOLERU, GANG ZHOU, QING CAO, PASCAL VICAIRE, JOHN A. STANKOVIC, TAREK F. ABDELZAHER, JONATHAN HUI and BRUCE KROGH

Volcano monitoring…

- Traditional approach: Bulky and sensitive sensors collecting info. into flash drives. Field researchers periodically harvest data
- Volcano sensing required high fidelity and high data rates (compared to other environment monitoring such as temperature).
  - 100 Hz with 24 bit accuracy
  - Design decision to either transmit or capture - assuming back-to-back events will be rare

Evaluation

- Overall network uptime
  - Higher for sensors than for the base station. Frequent trips to replace batteries on the sensors. Base stations lost wall-power frequently
- Individual node uptime
  - Safe for durations when they had a bug - fairly good
- Event detector accuracy was extremely poor ~1%
  - Hardware limitation
- Data yield and fetch latency affected by design decisions (simultaneous capture and transmit)
- Time synchronization failure - some software bugs not seen in lab
  - Time rectification to recover some timing data

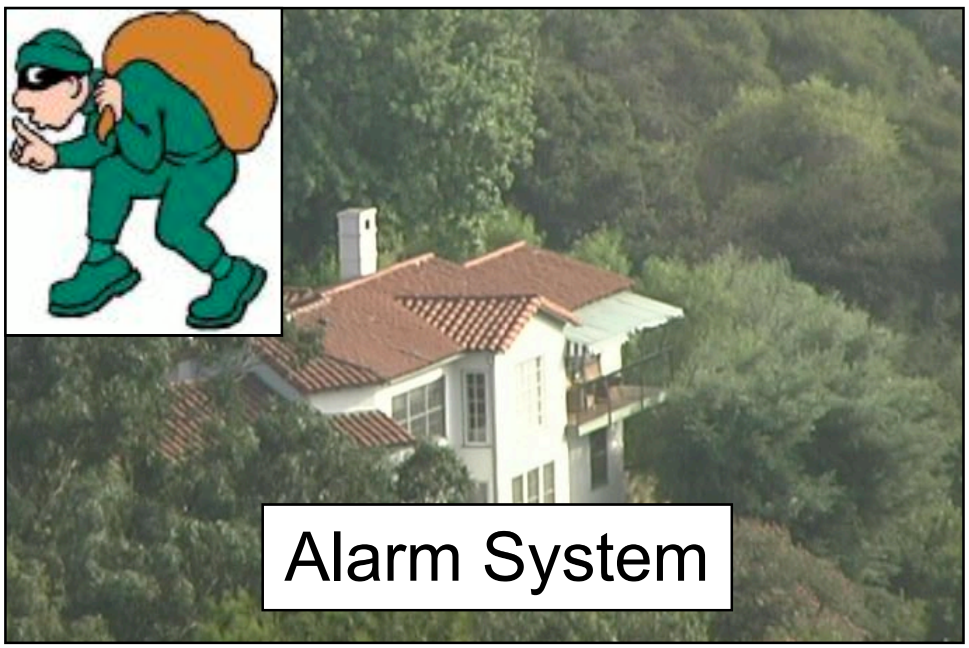
Lessons learnt

- Ground truth and self-validation are important
- Coping with infrastructure and protocol failures
- Cross-domain collaboration: science researchers would want the data immediately. Waiting for timer rectication etc. might strain relationship

Vigilnet Applications

Wildlife Monitoring

Flock Protection



Alarm System

Border Surveillance

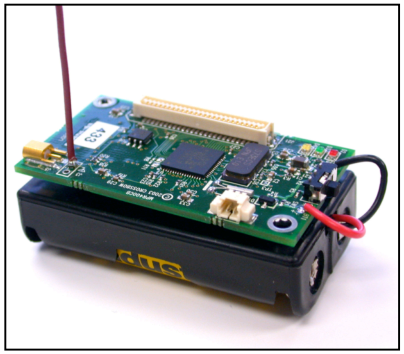
Power Consumption: An Important Issue in Surveillance Systems

- No power management ⇒ 4 days lifetime!

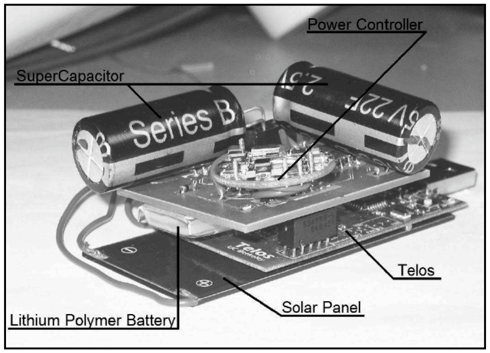
- Power management ⇒ 10 months lifetime!

State of the Art: Hardware

- Power efficient hardware
  - MICA2, MICAz, XSM, etc…



- Energy scavenging hardware
  - Vibrations. Roundy et al., “A Study of Low Level Vibrations as a Power Source for Wireless Sensor Network”, Computer Communications, 2003.
  - Sun light. Perpetually powered Telos.

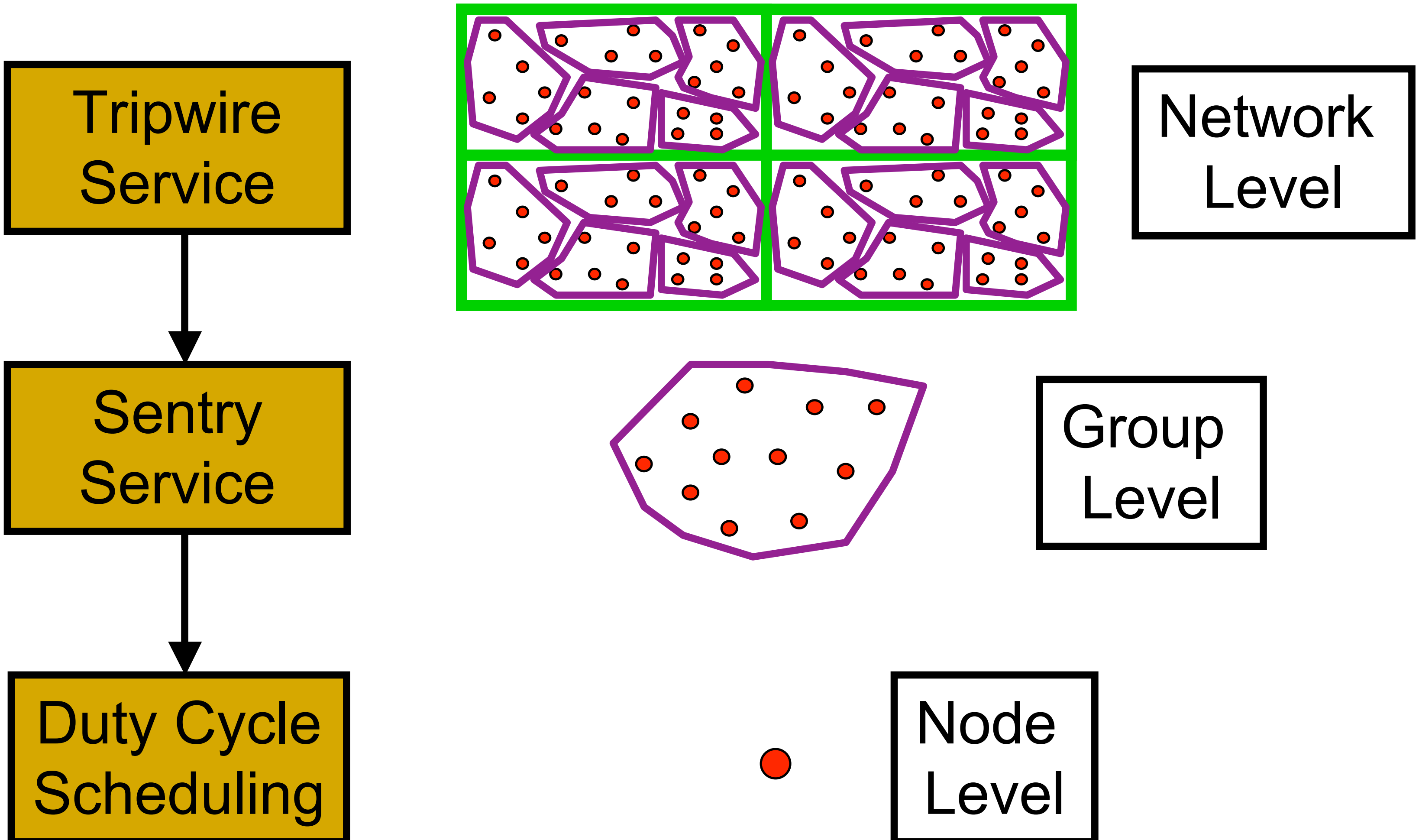


State of the Art: Software

- Synchronization and coordination: Nodes turn on only for specific tasks of which the execution time is known in advance.
- Data aggregation and compression: Nodes reduce amount of transferred data to decrease energy costs.
- Coverage control: Nodes providing redundant sensing coverage are turned off.
- Duty cycle scheduling: Nodes alternate between on and off states at a fast rate, which still allow them to detect slow paced targets.

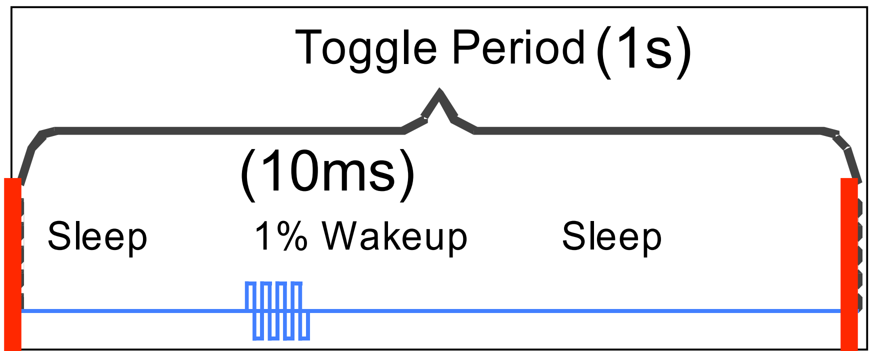
Power Management in VigilNet

- Combination of three schemes in real system.

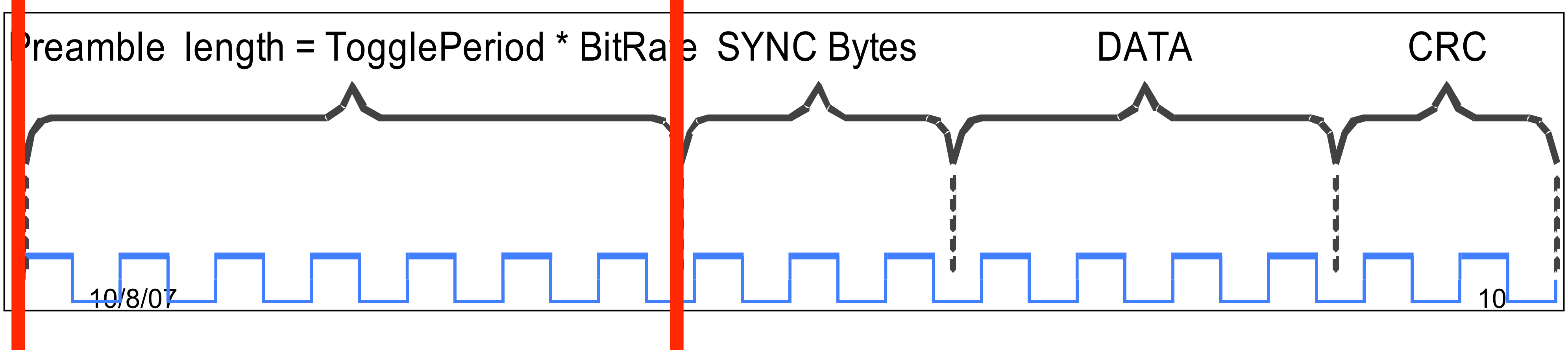


Putting Nodes Into a Sleep State

- Putting nodes to sleep as often and as long as possible.
- Sleeping mode: node wakeup 1% of the time.

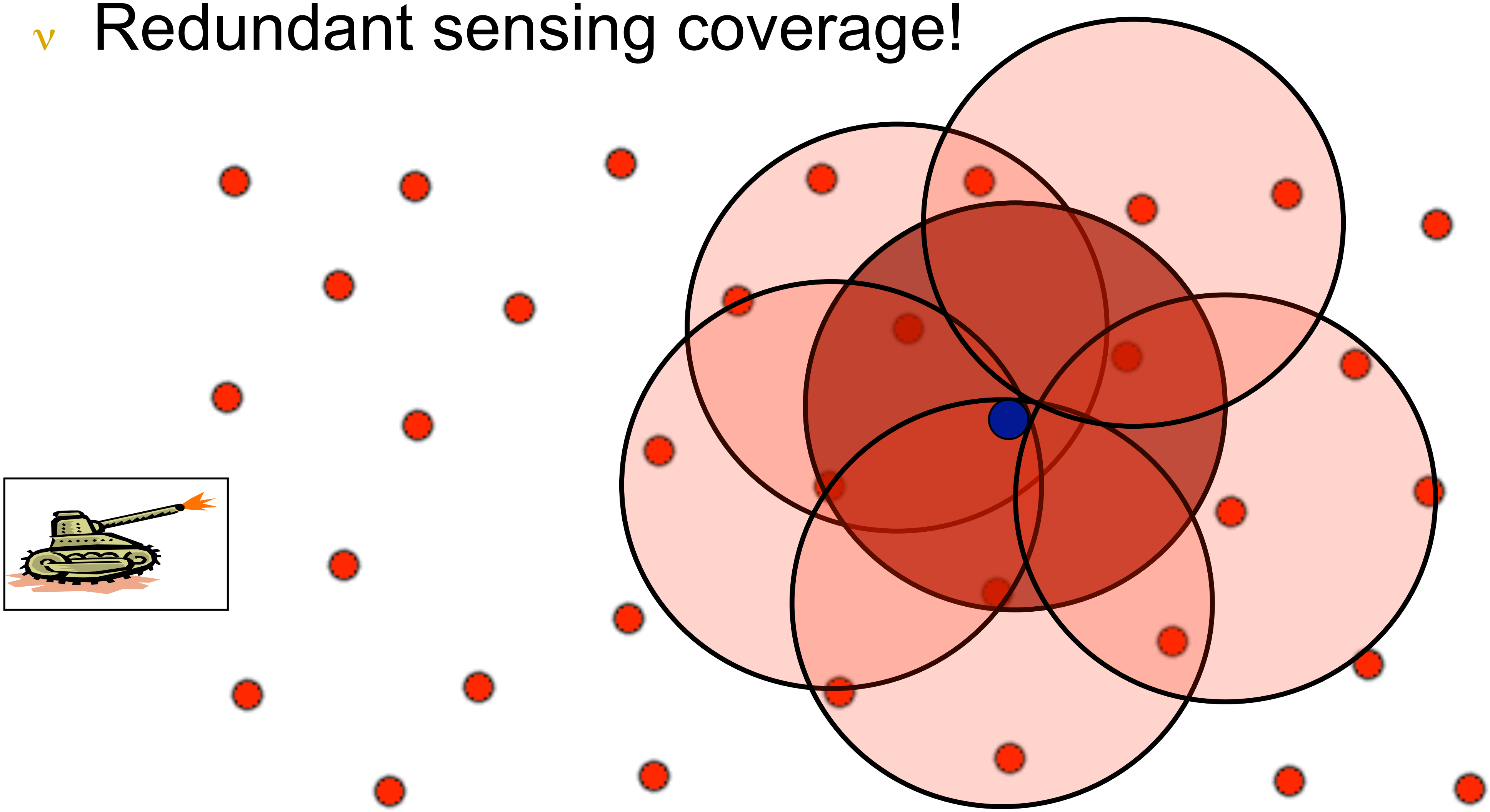


- Wakeup operation: send message with long preamble.

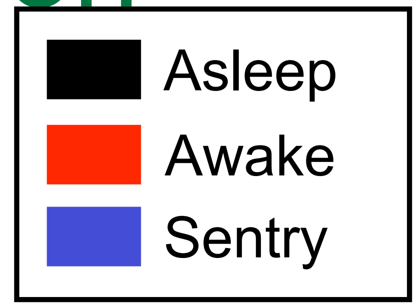


Group Level: Sentry Selection

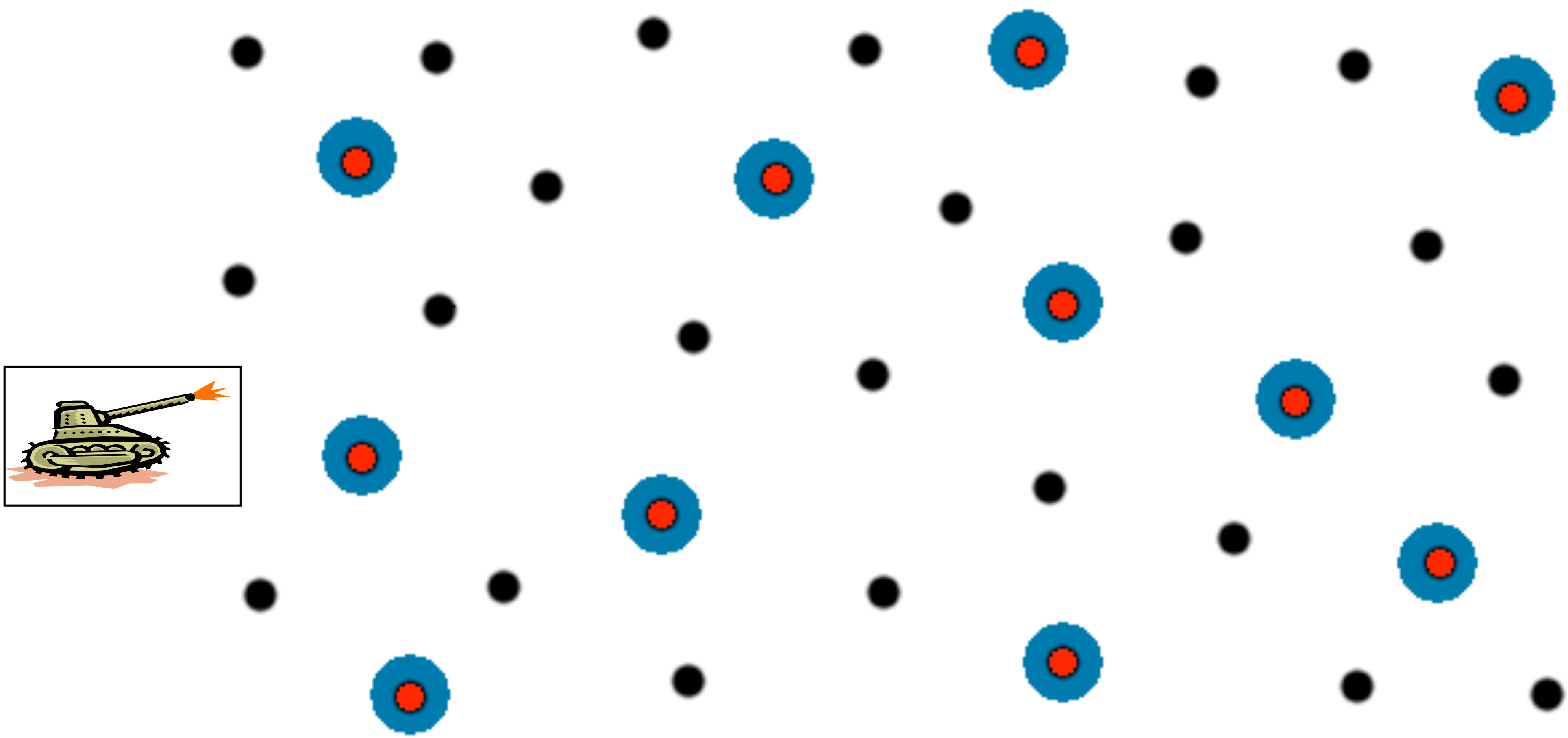
- Redundant sensing coverage!



Group Level: Sentry Selection

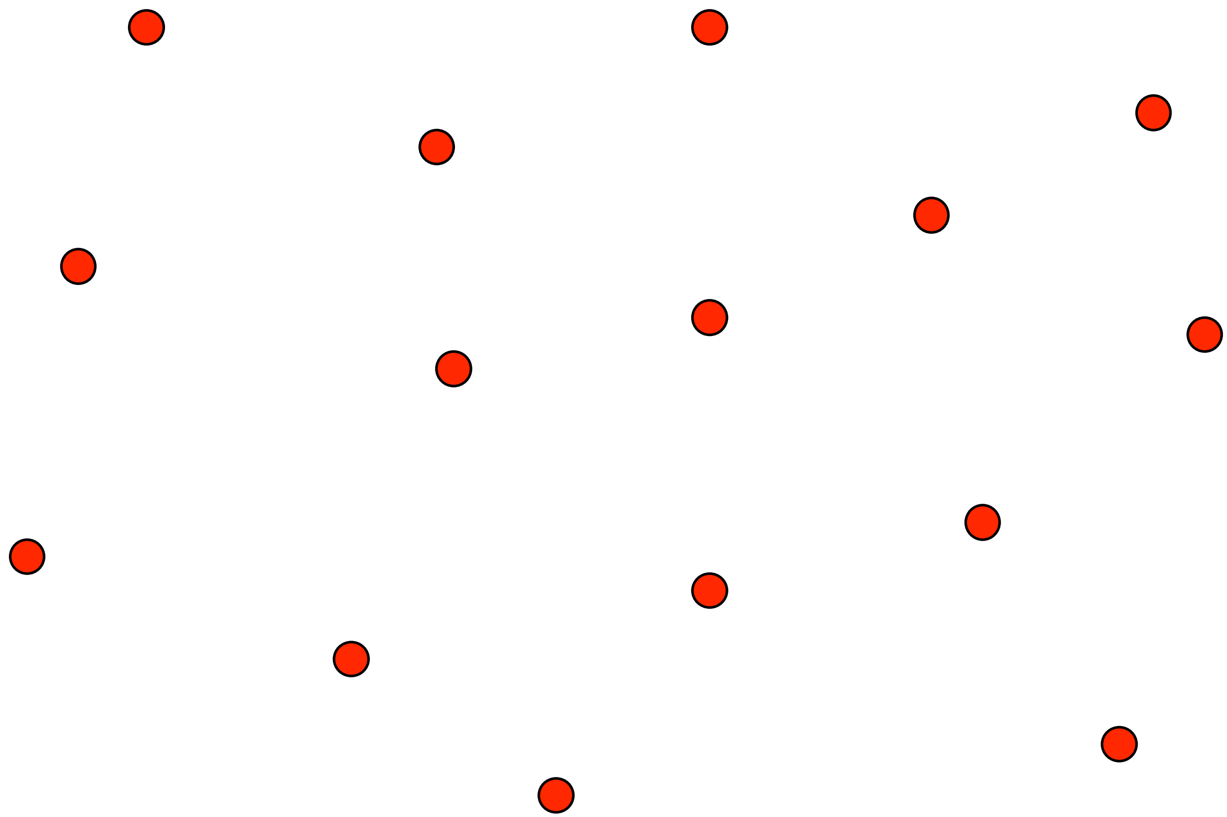


- Sentry selection and rotation.



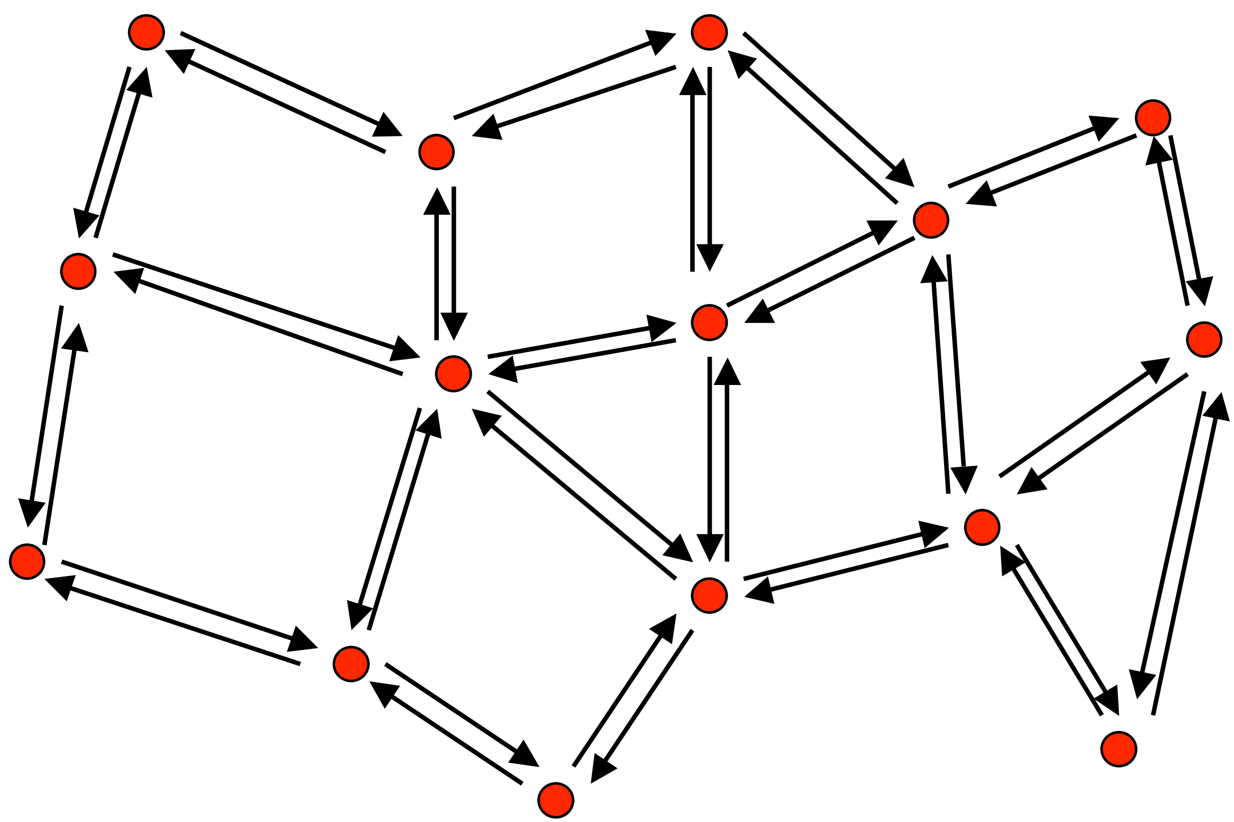
Group Level: Sentry Selection

- How are the sentries selected?



Group Level: Sentry Selection

- 1. Neighbors exchange “hello” message (ID + position + nb of neighbors + energy).



Group Level: Sentry Selection

- 2. Each node selects a delay according to its energy resources and coverage.

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Delay = Function (Energy + Coverage)
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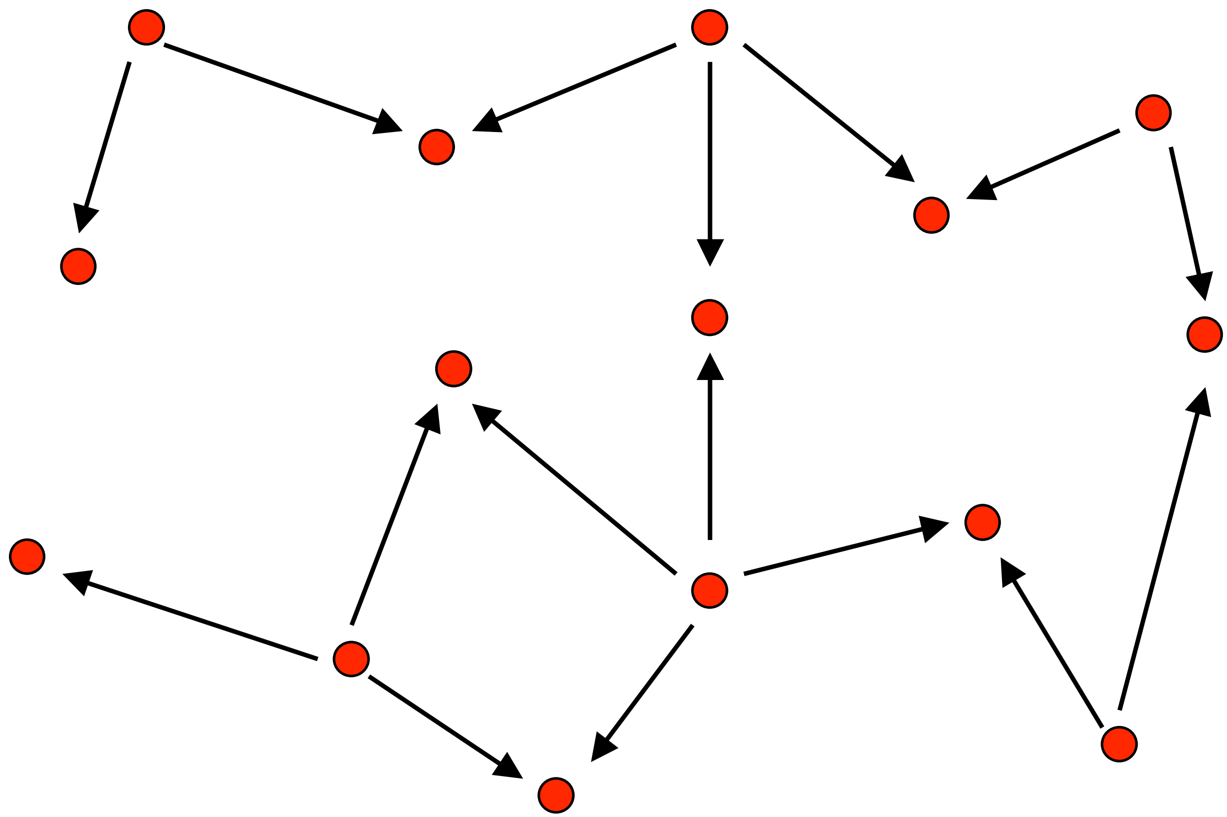
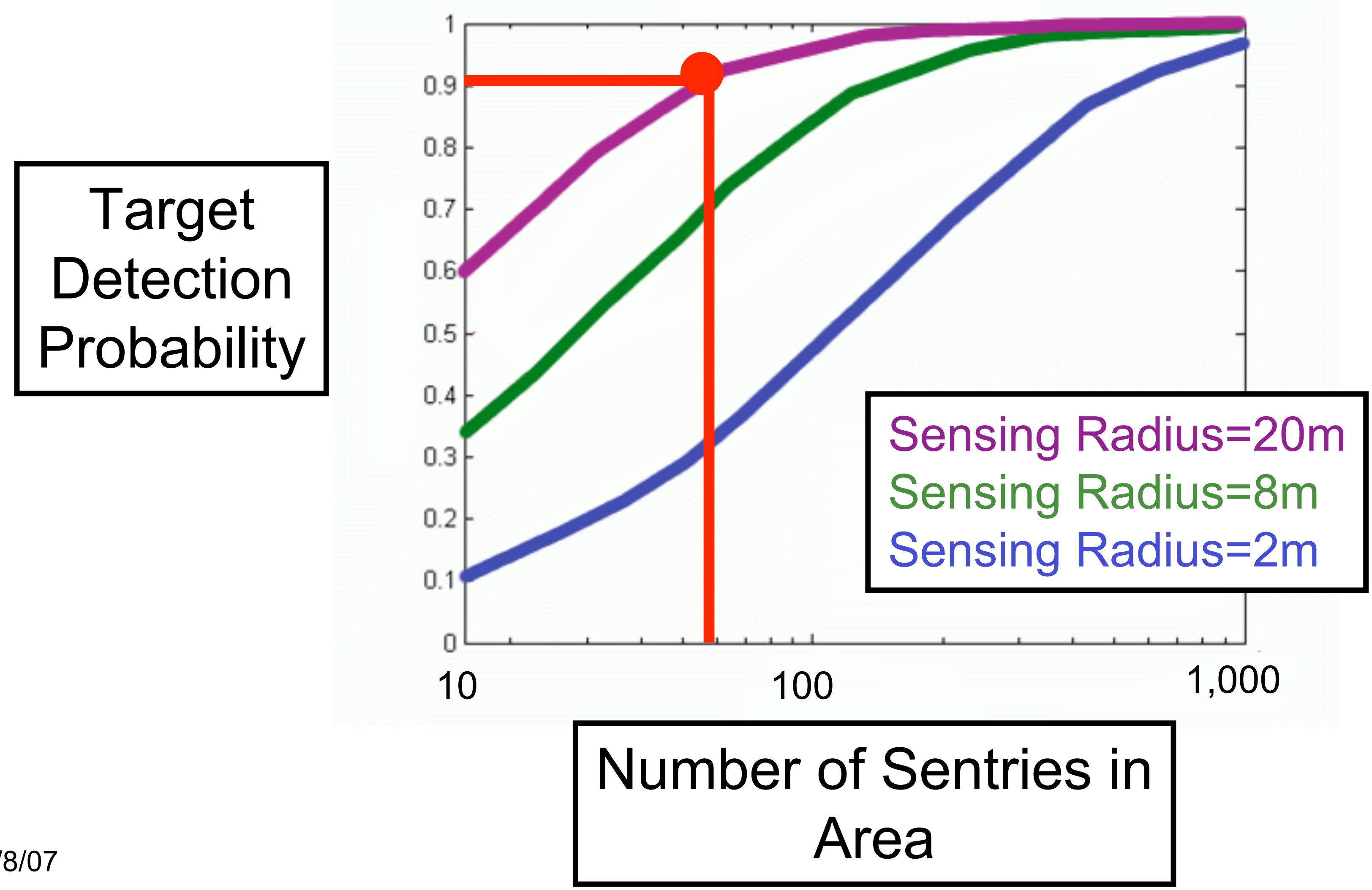
Group Level: Sentry Selection

- 3. Once the delay is elapsed, a node announces itself as a sentry.



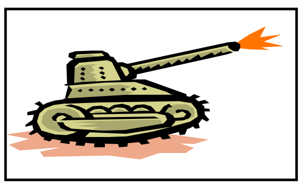
Group Level: Sentry Selection

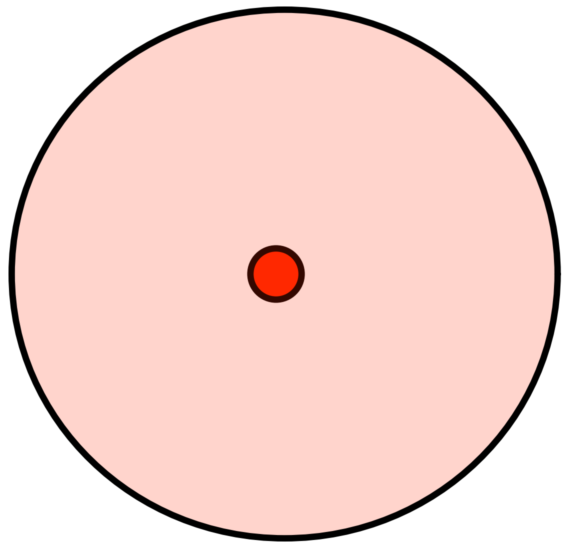
- Tradeoff: detection probability versus density.



Node Level: Duty Cycle Scheduling

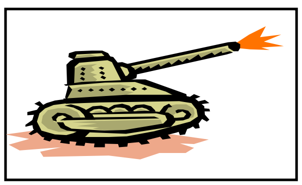
- Target takes time to go through the network.

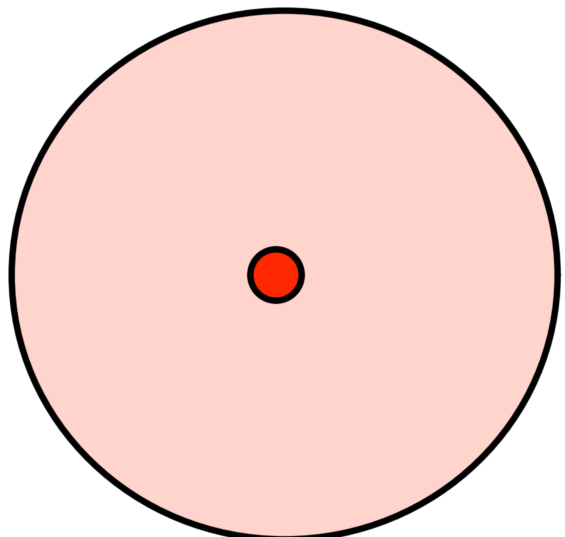


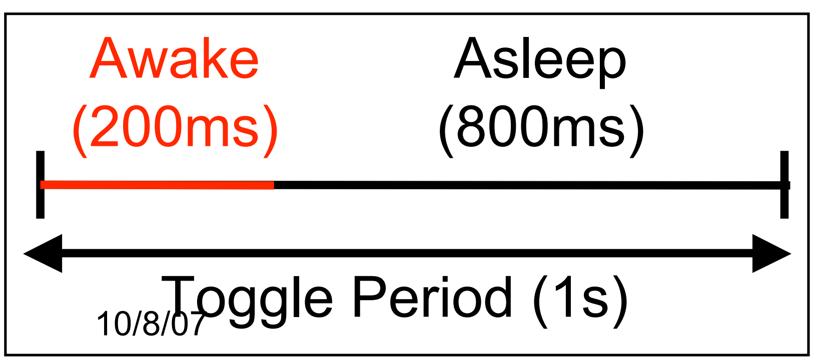


Node Level: Duty Cycle Scheduling

- Target takes time to go through the network $\Rightarrow$ duty cycle scheduling.

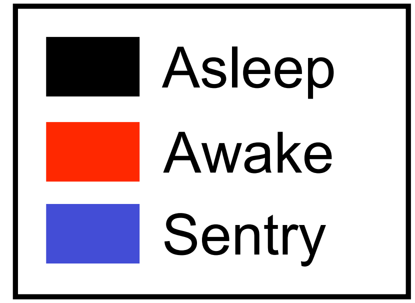


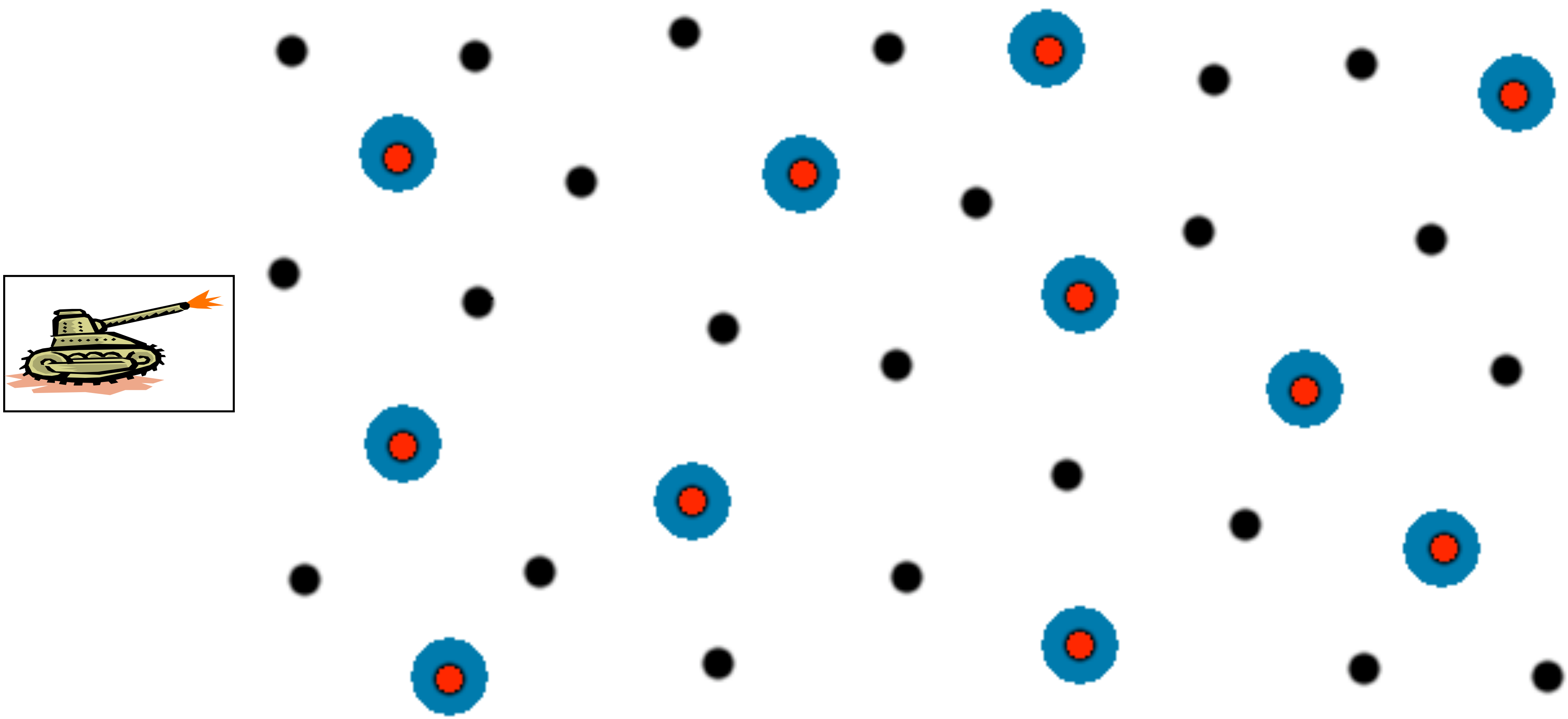




Node Level: Duty Cycle Scheduling

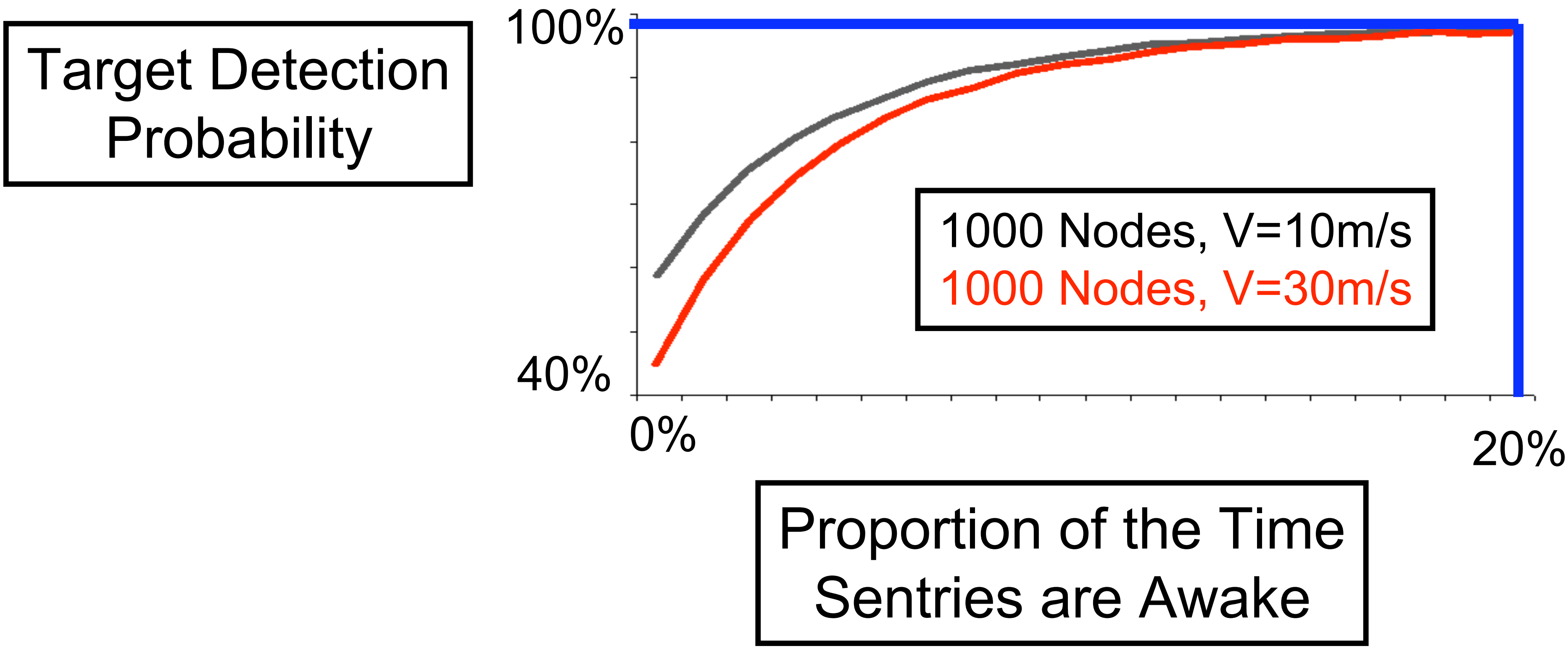
- Putting it all together.





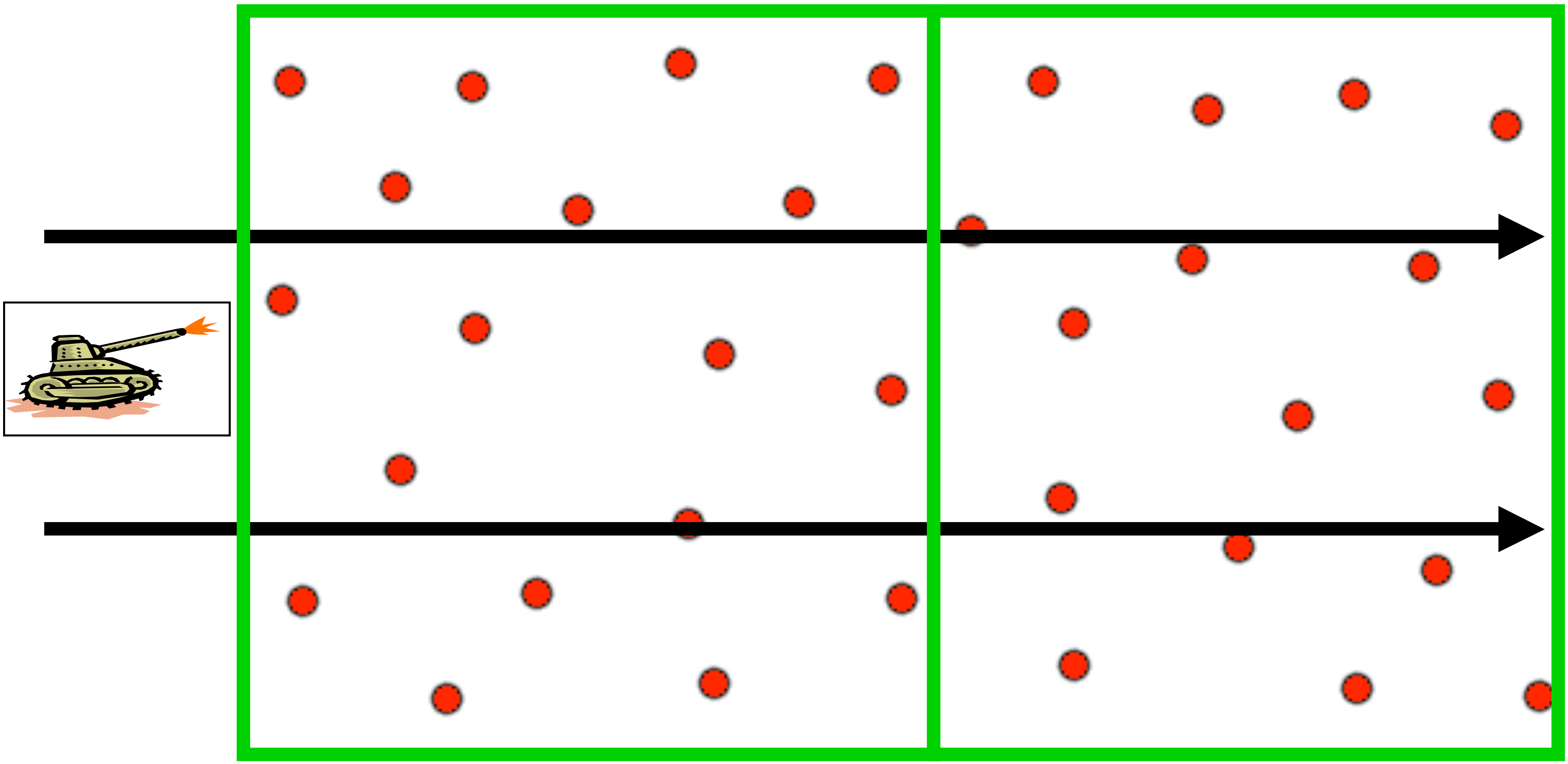
Node Level: Duty Cycle Scheduling

- Tradeoff: detection probability versus duty cycle.



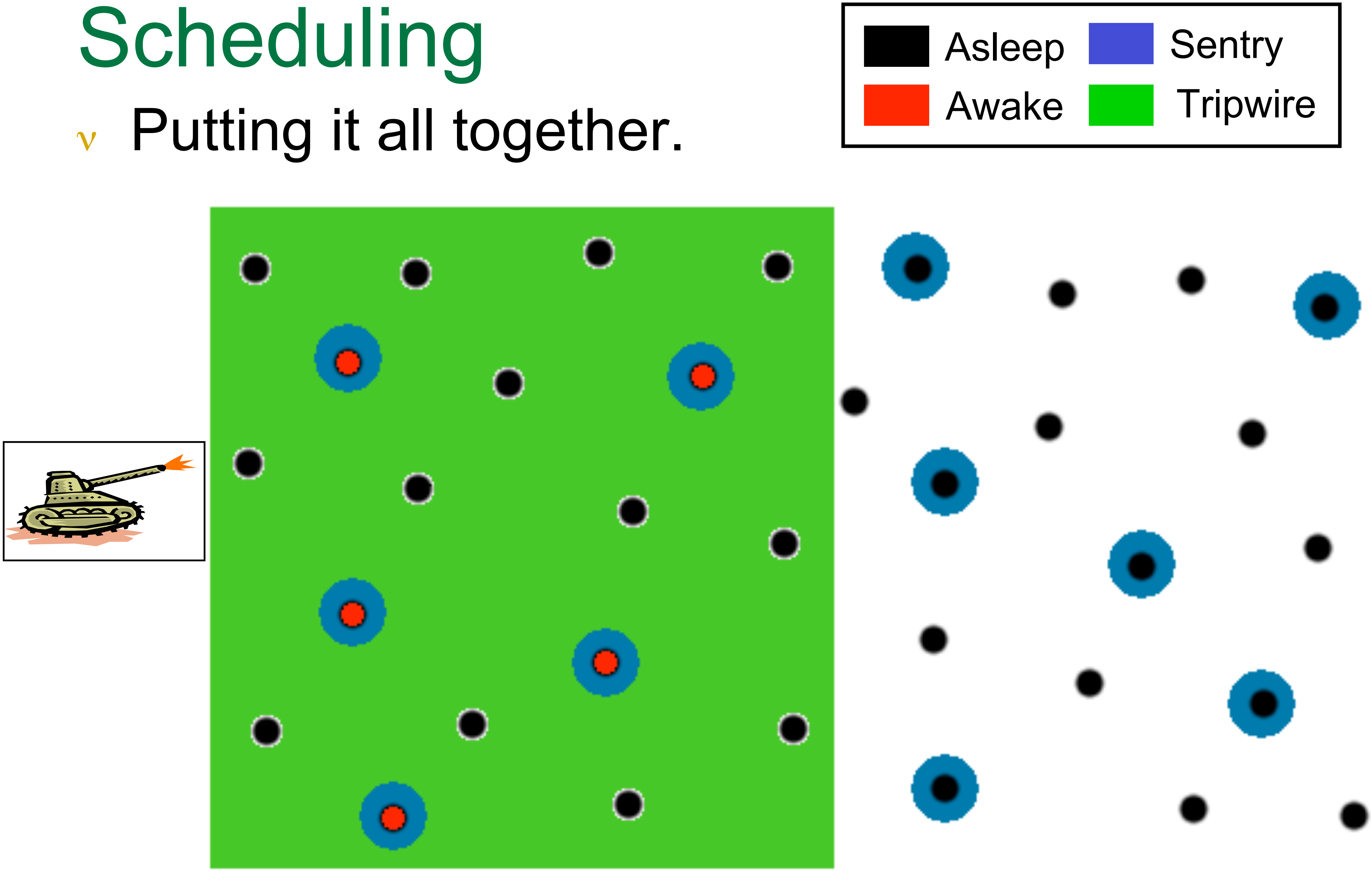
Network Level: Tripwire Scheduling

- Exploiting knowledge about the target.



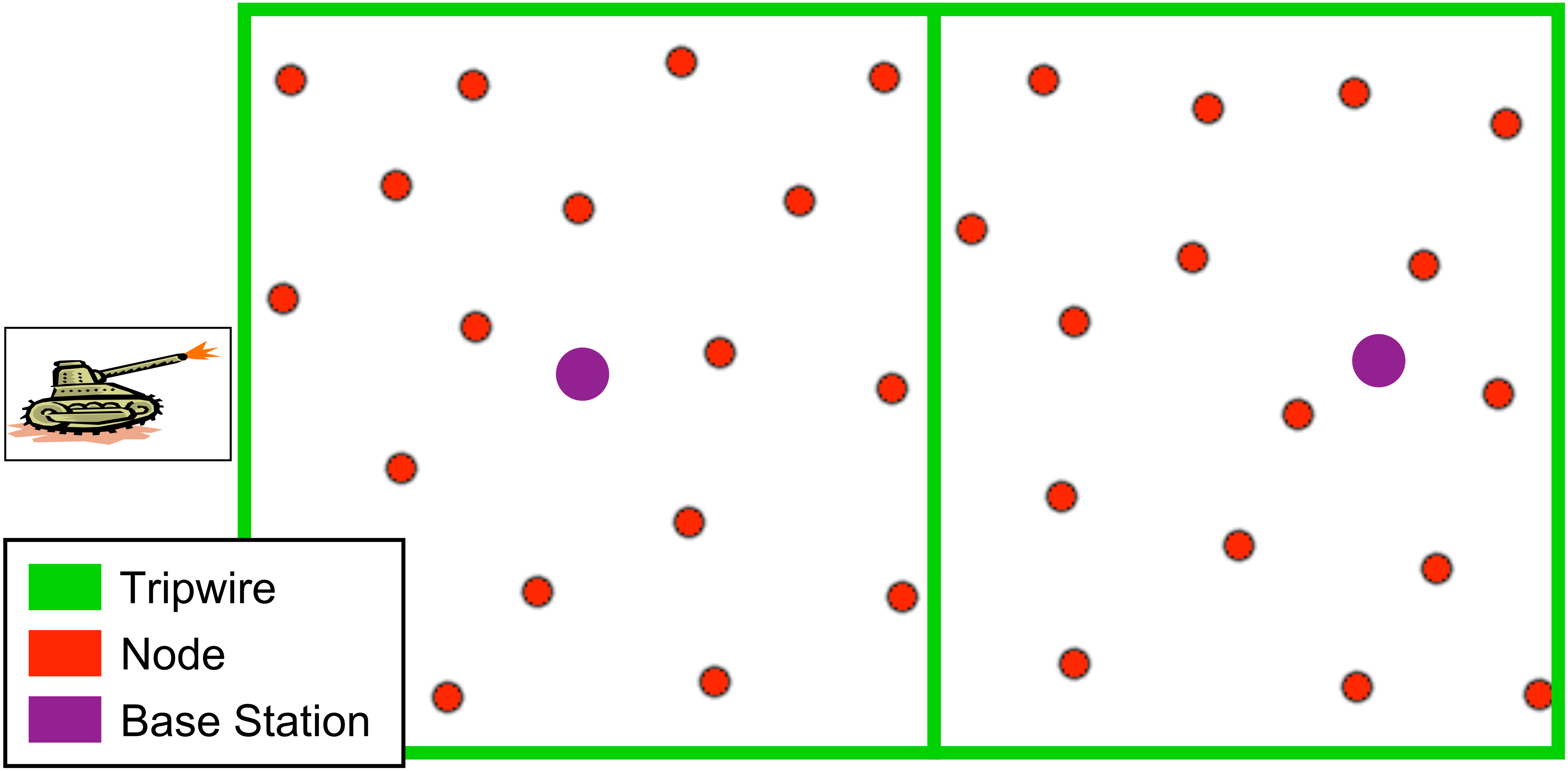
Network Level: Tripwire Scheduling

- Putting it all together.



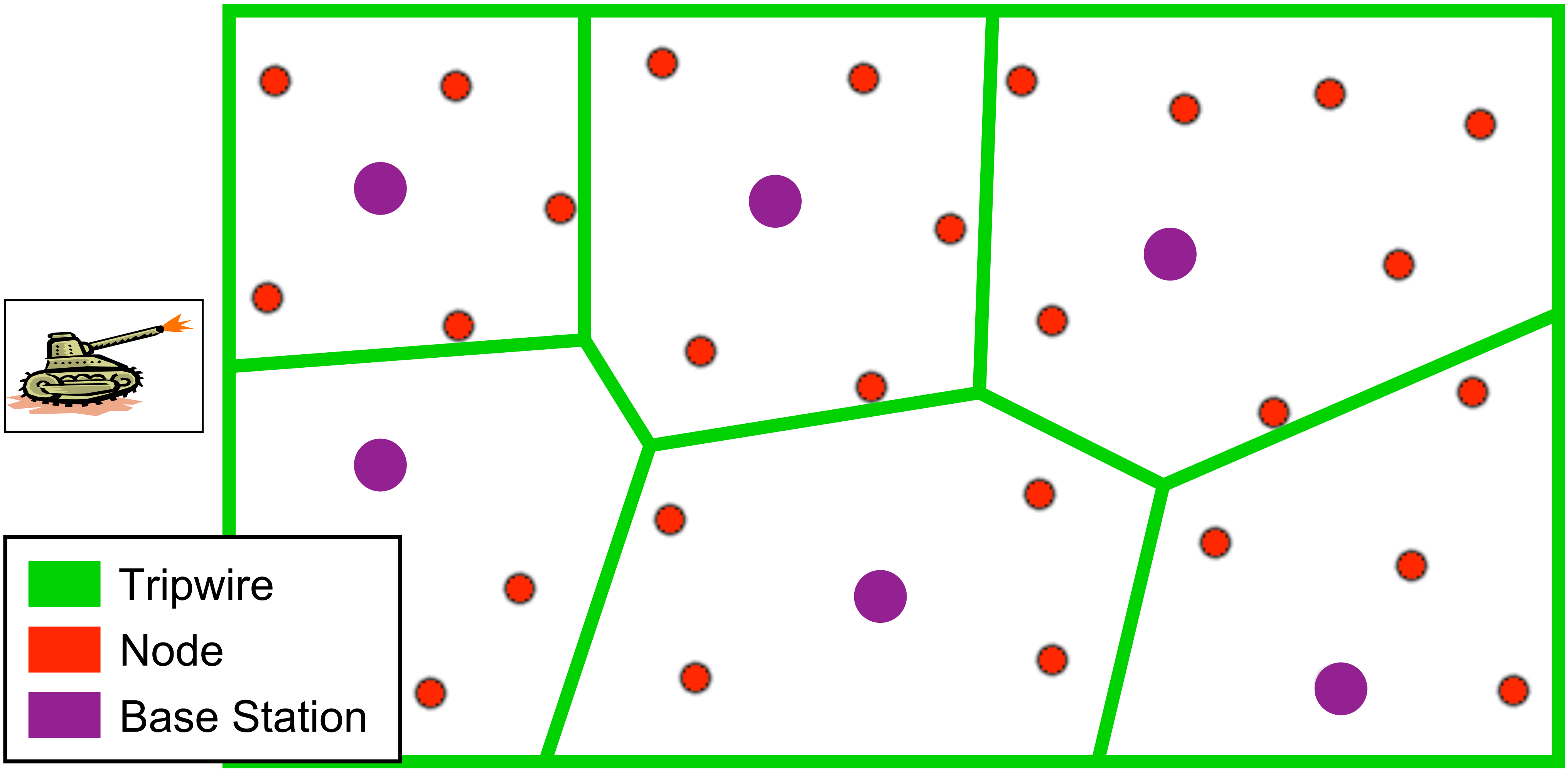
Network Level: Tripwire Scheduling

- Each base station defines a tripwire; a node pertains to the tripwire associated with the closest base.



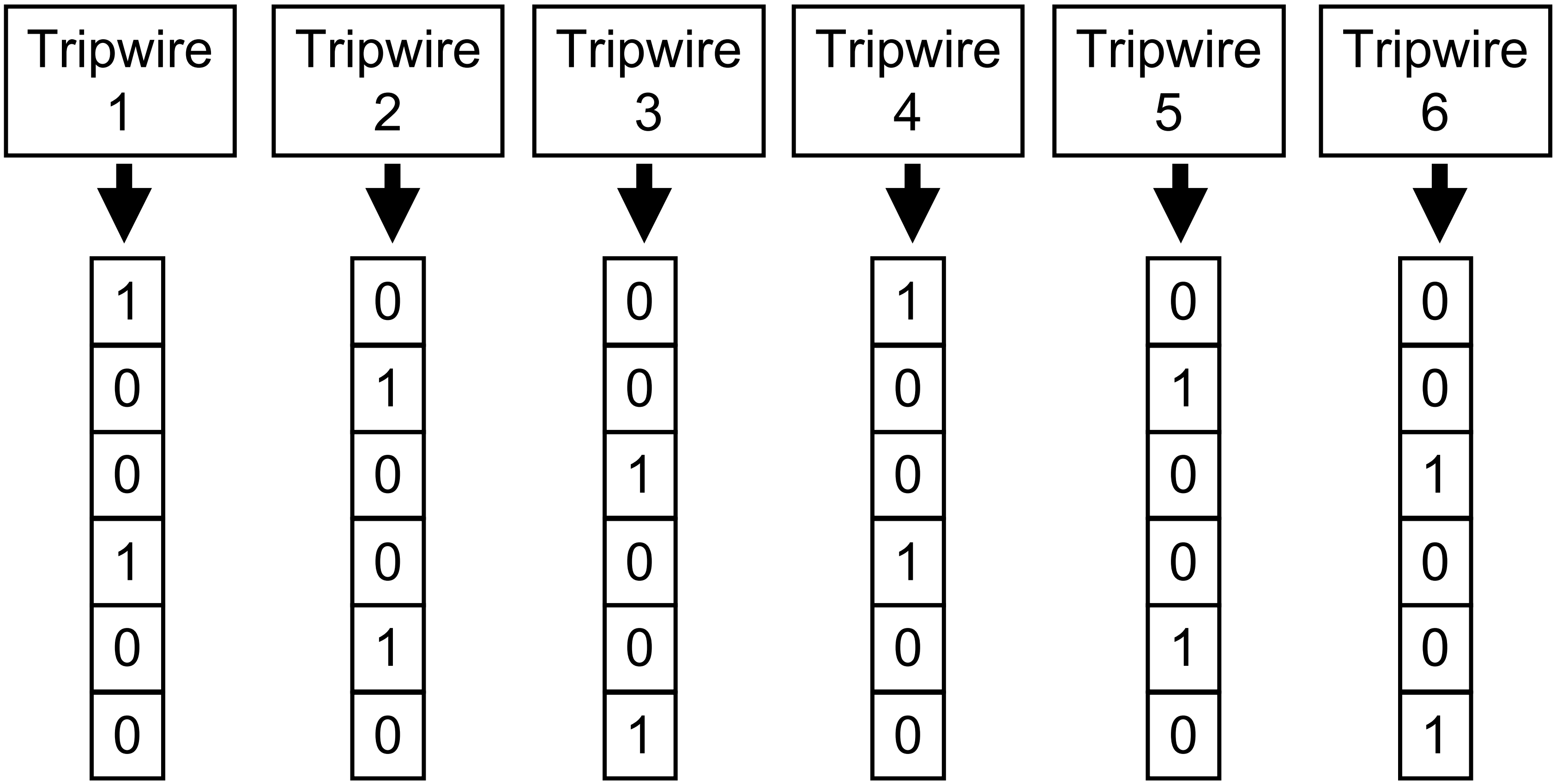
Network Level: Tripwire Scheduling

- There are as many tripwires as base stations.



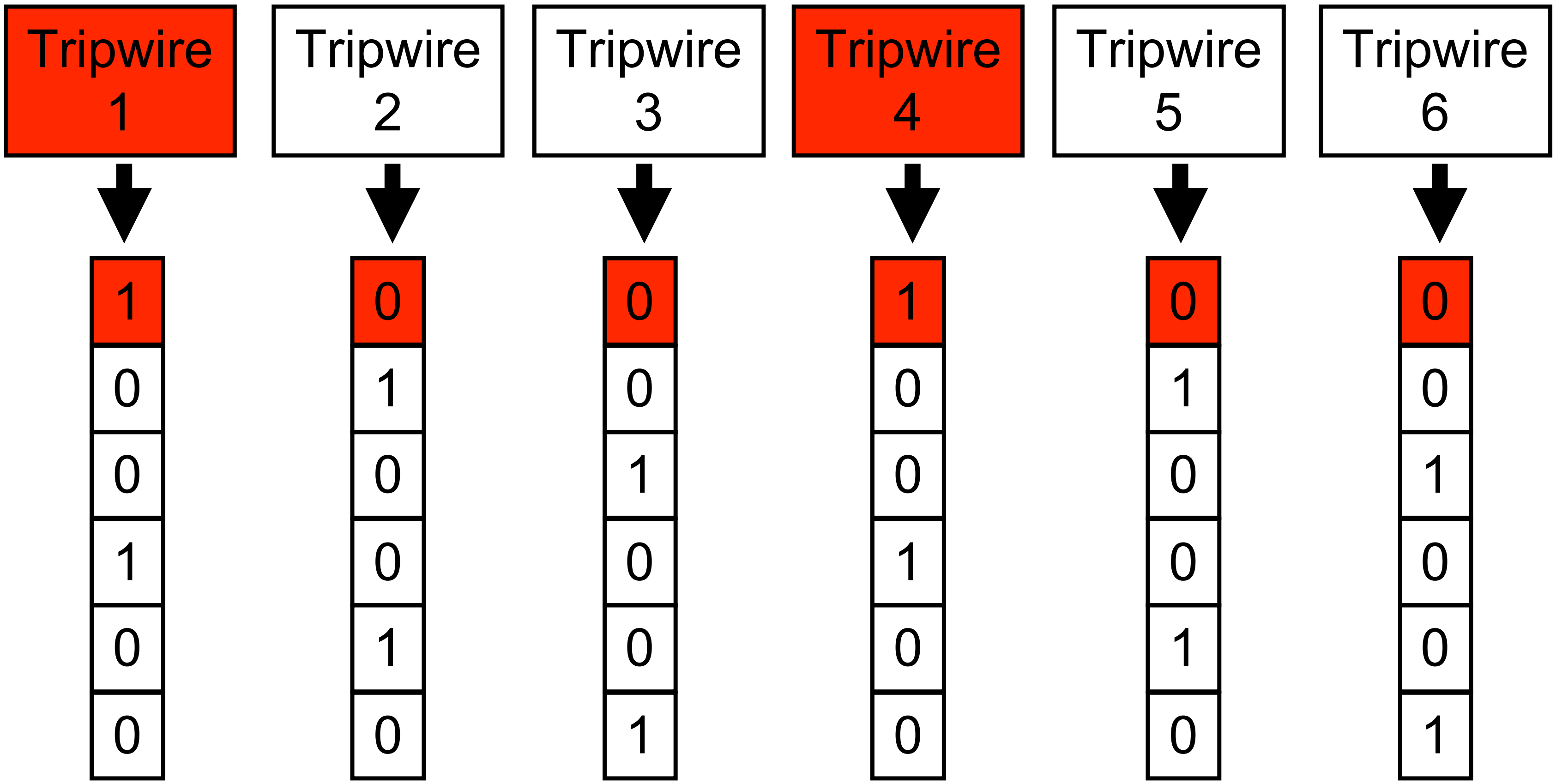
Network Level: Tripwire Scheduling

- Tripwire schedule specification:



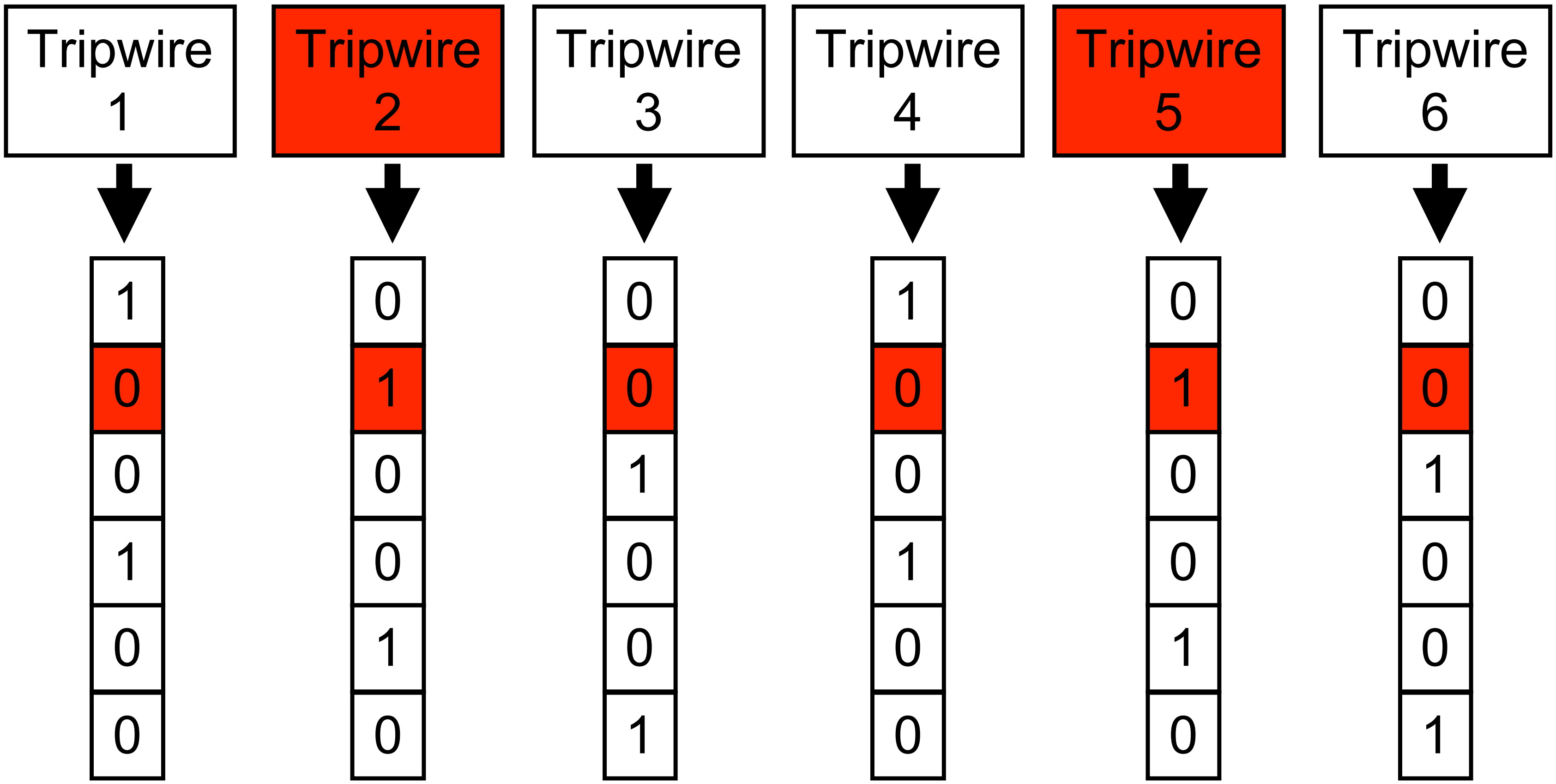
Network Level: Tripwire Scheduling

- Tripwire schedule specification:



Network Level: Tripwire Scheduling

- Tripwire schedule specification:



Network Level: Tripwire Scheduling

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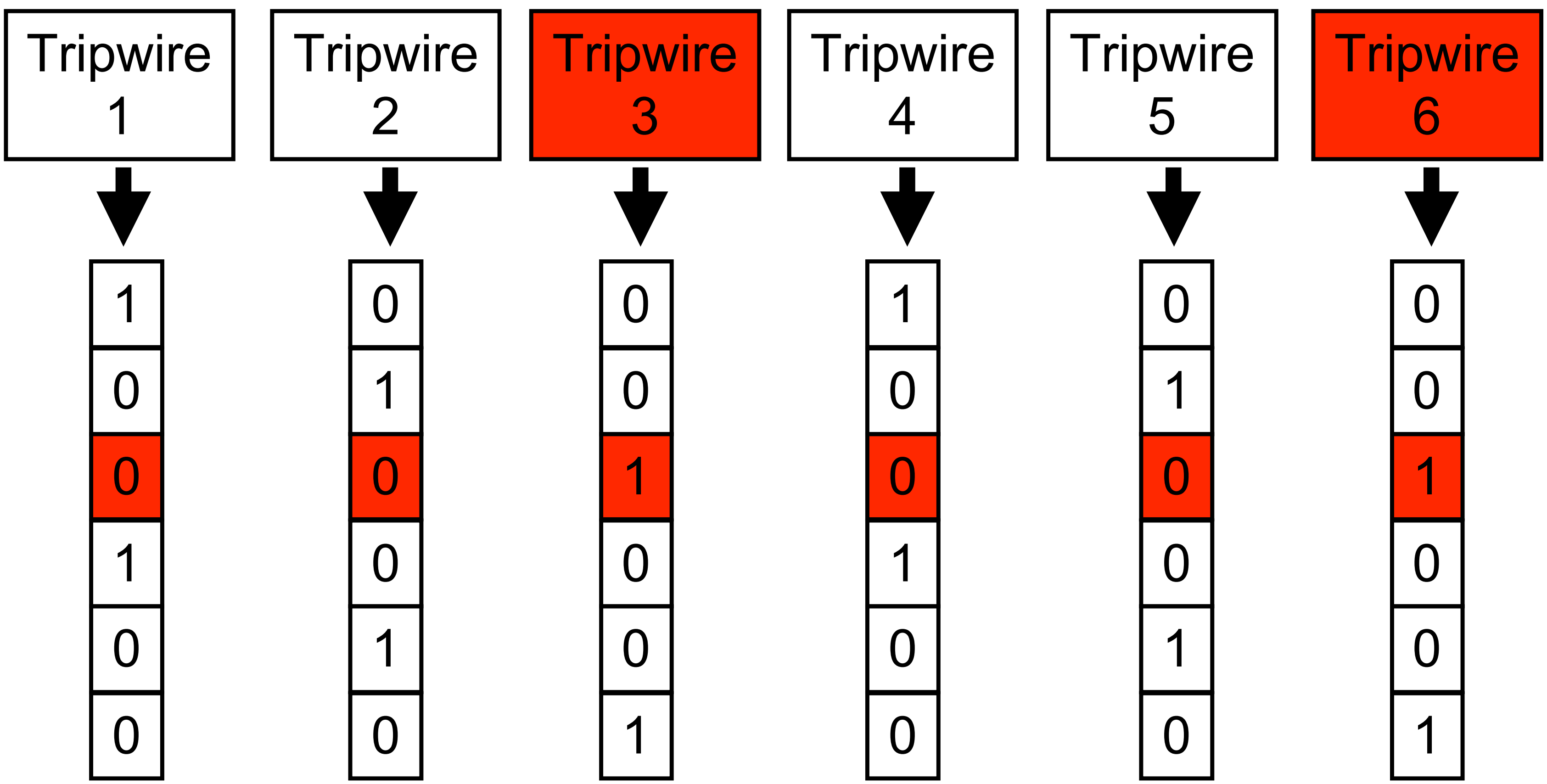

Network Level: Tripwire Scheduling

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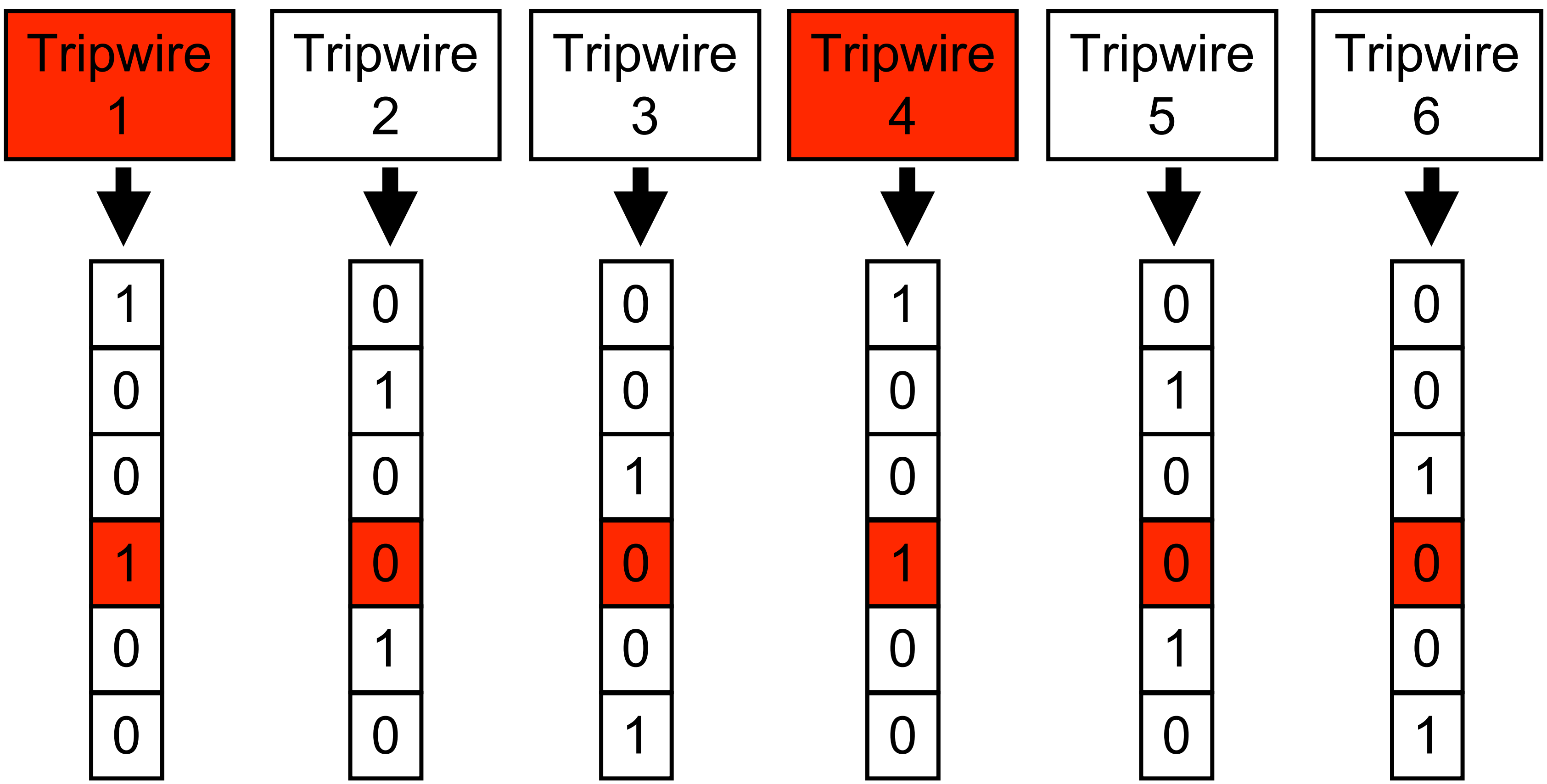

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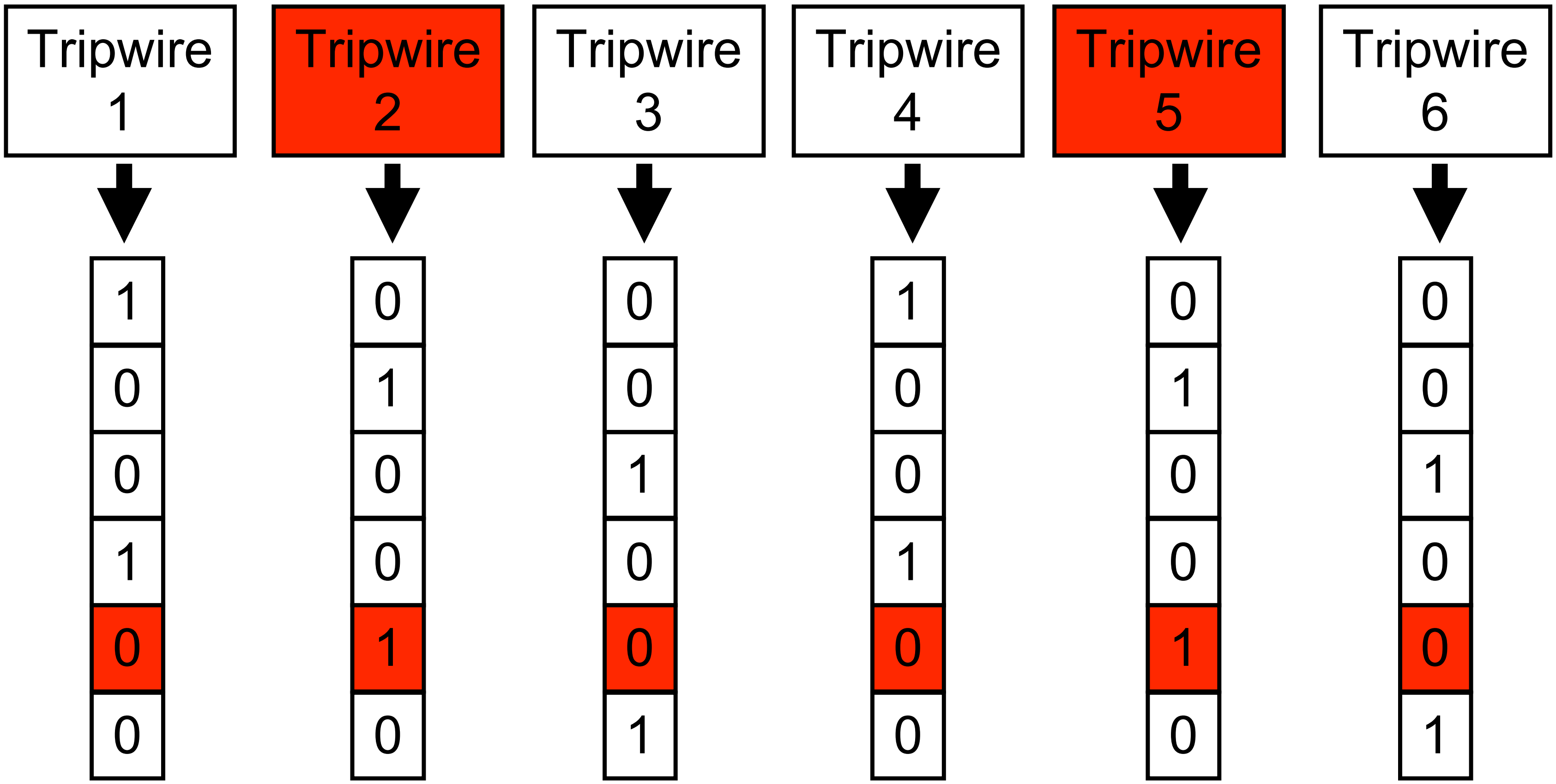

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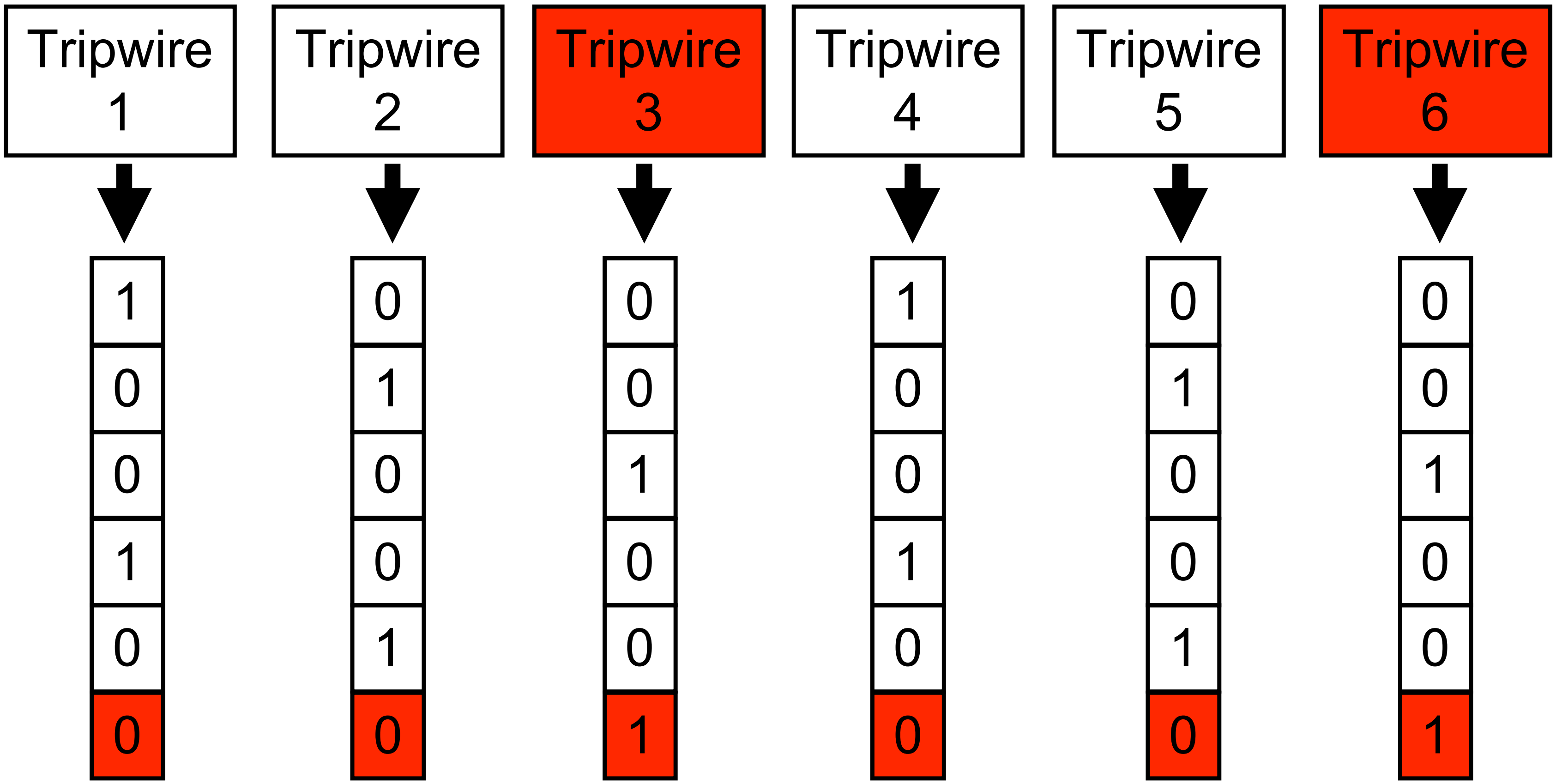

Network Level: Tripwire Scheduling

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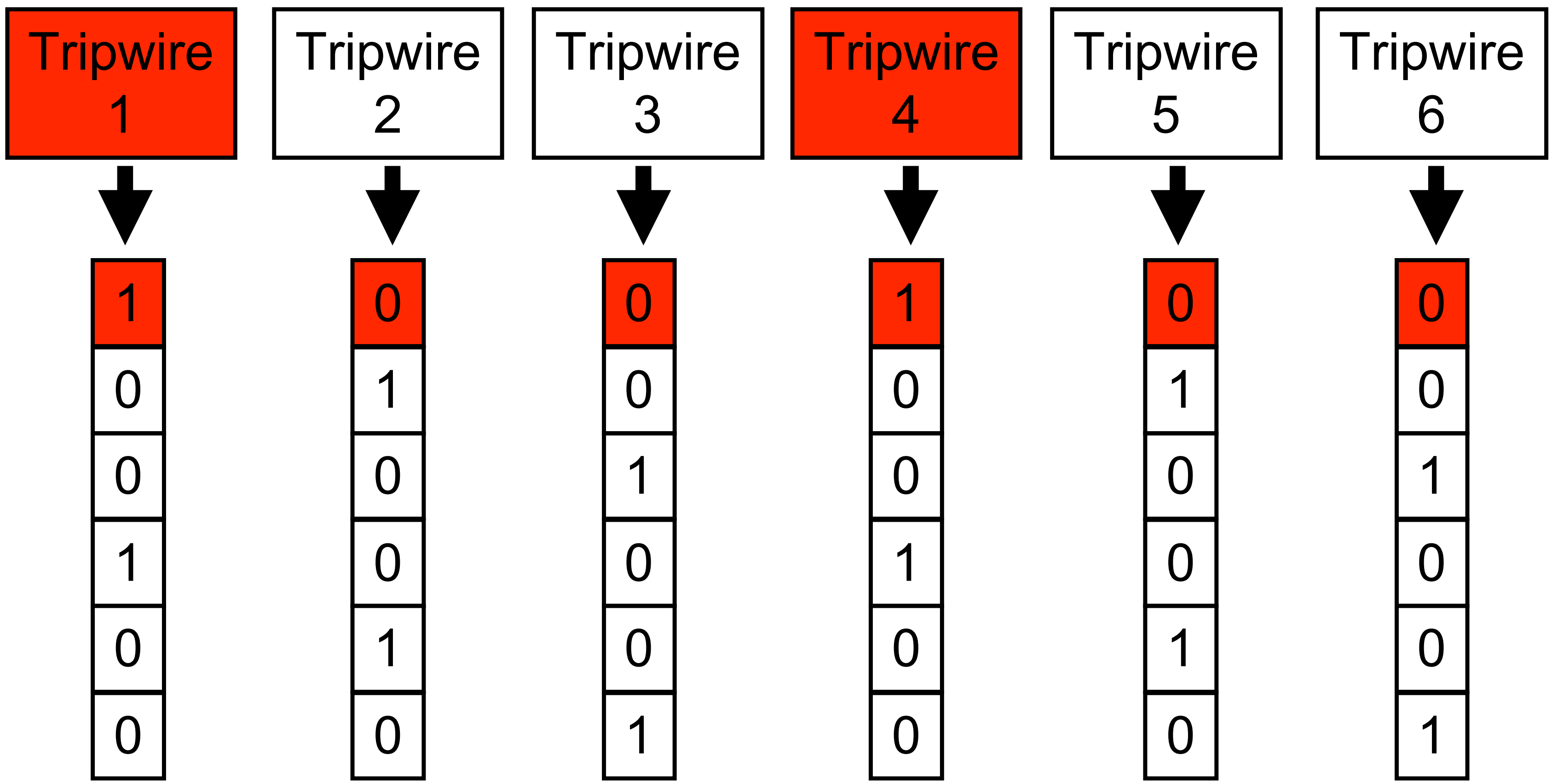
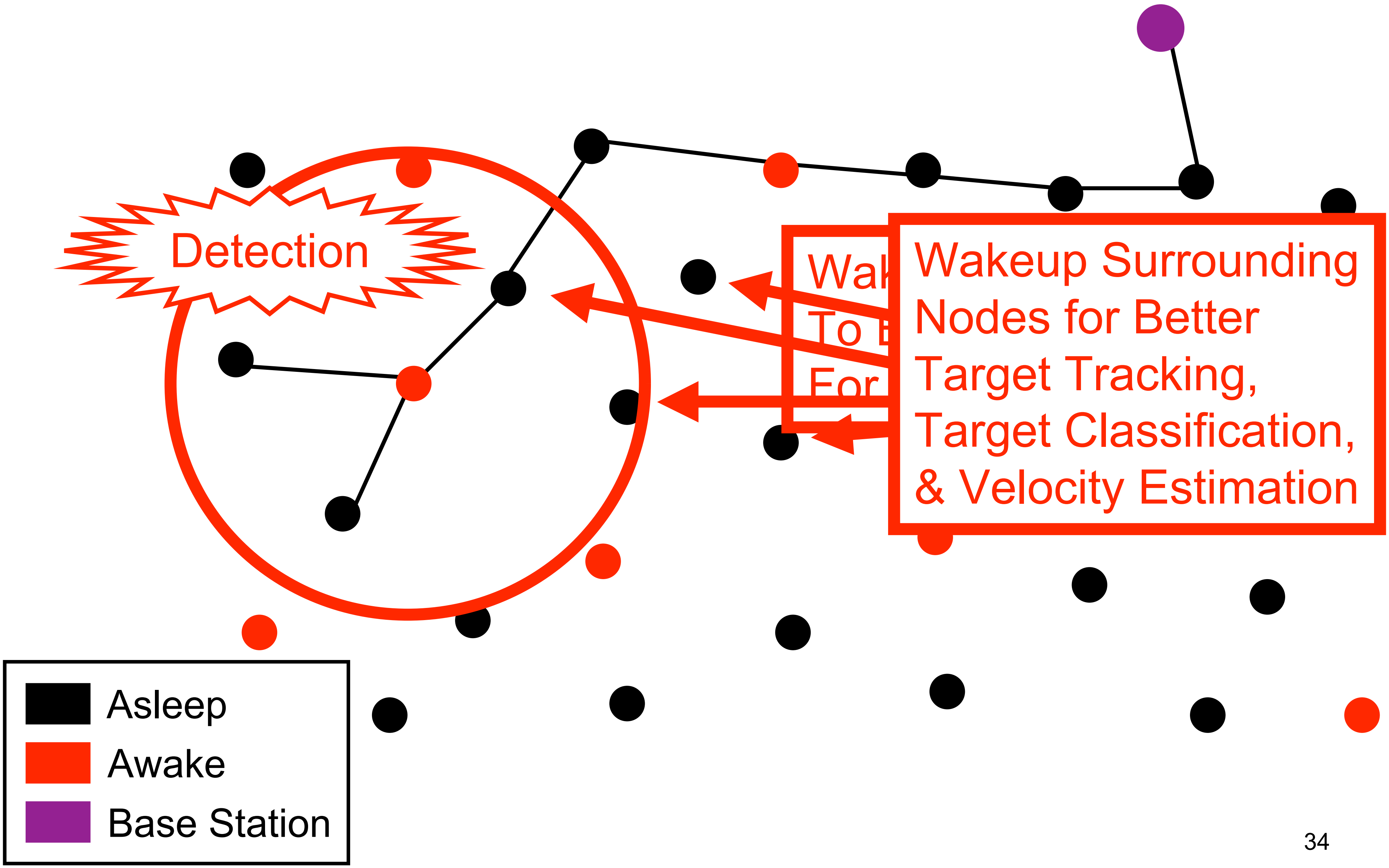
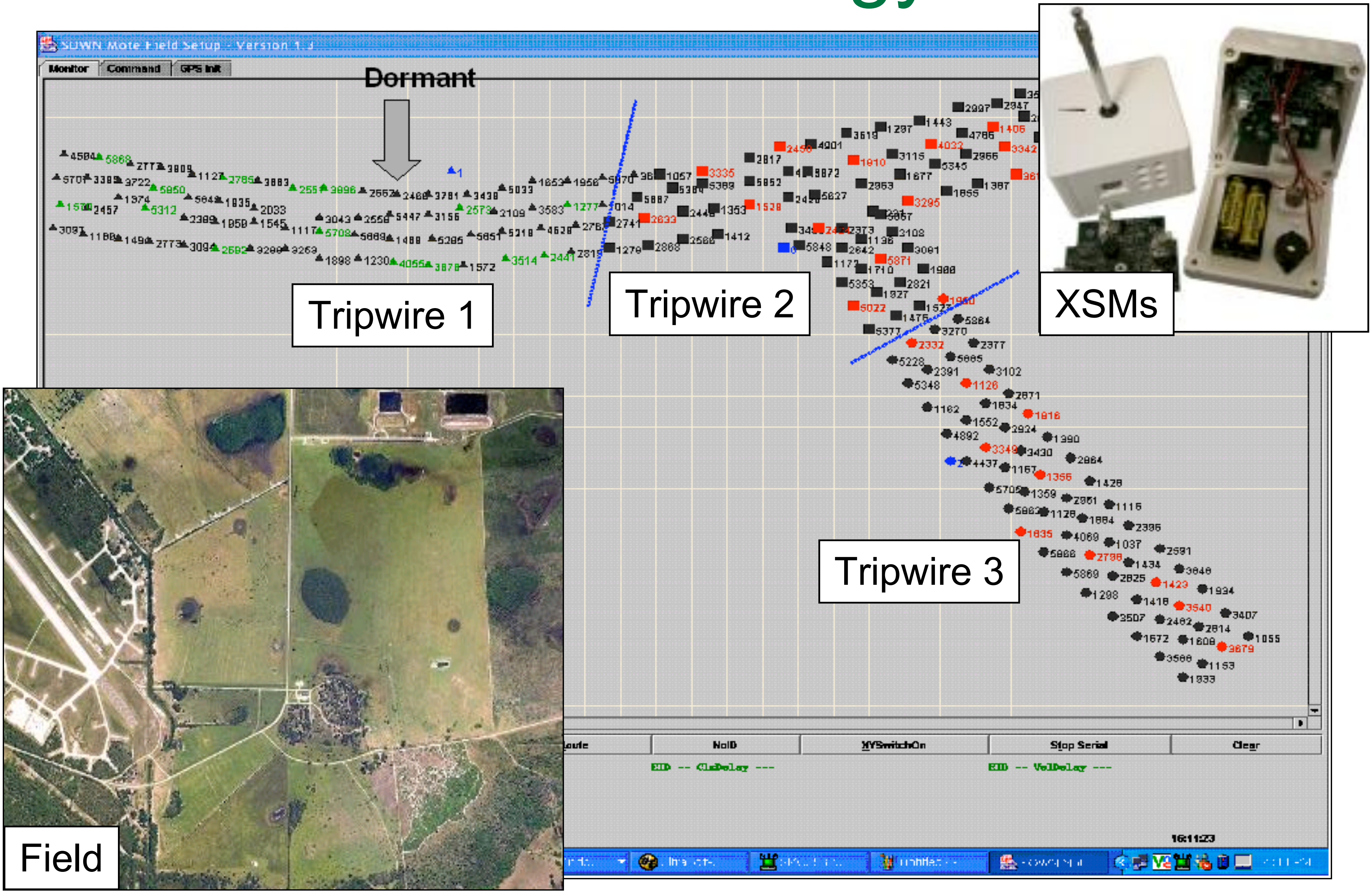


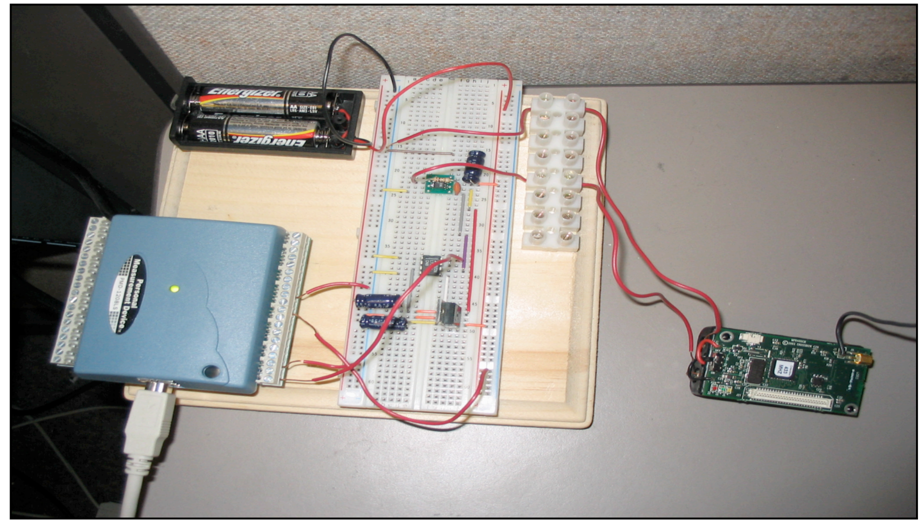
On-Demand Wakeup

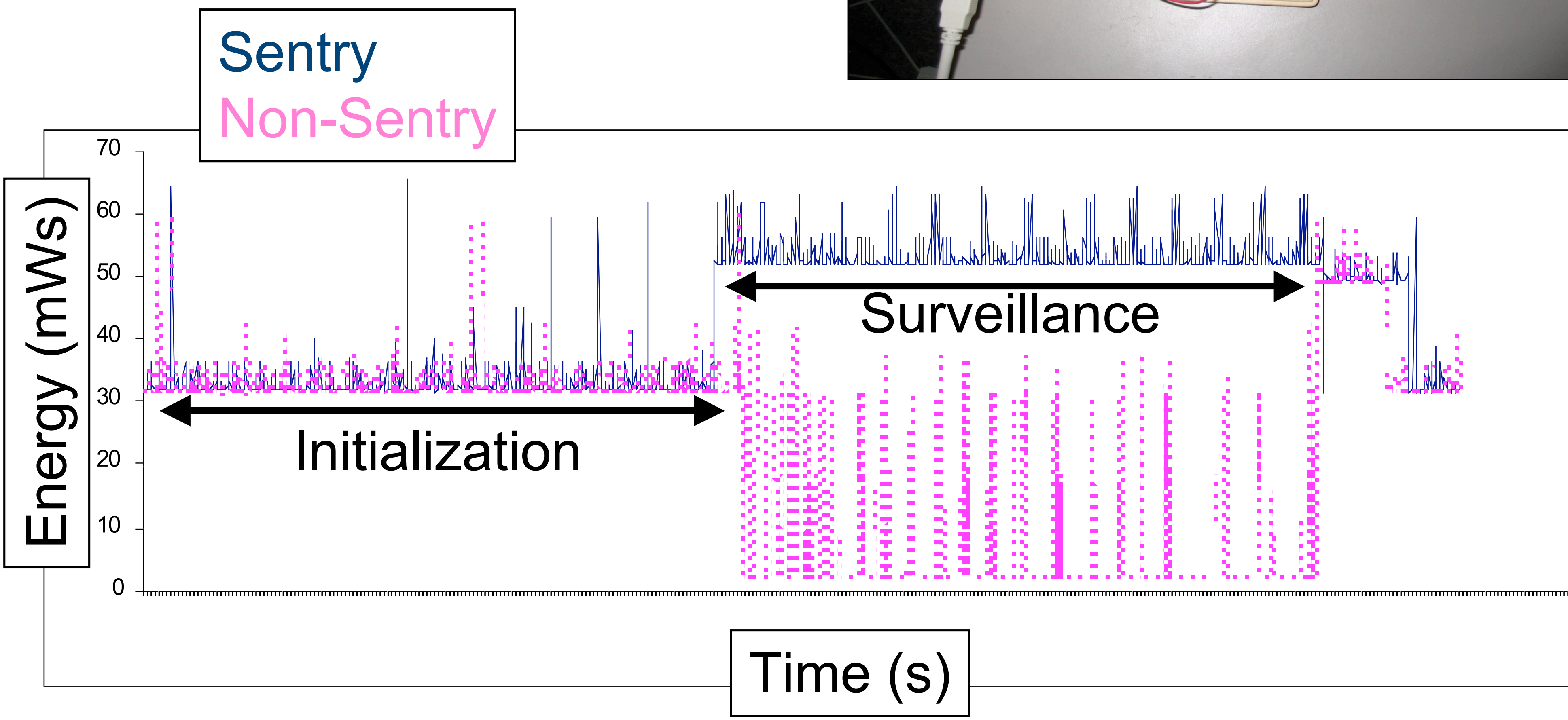


Evaluation Methodology

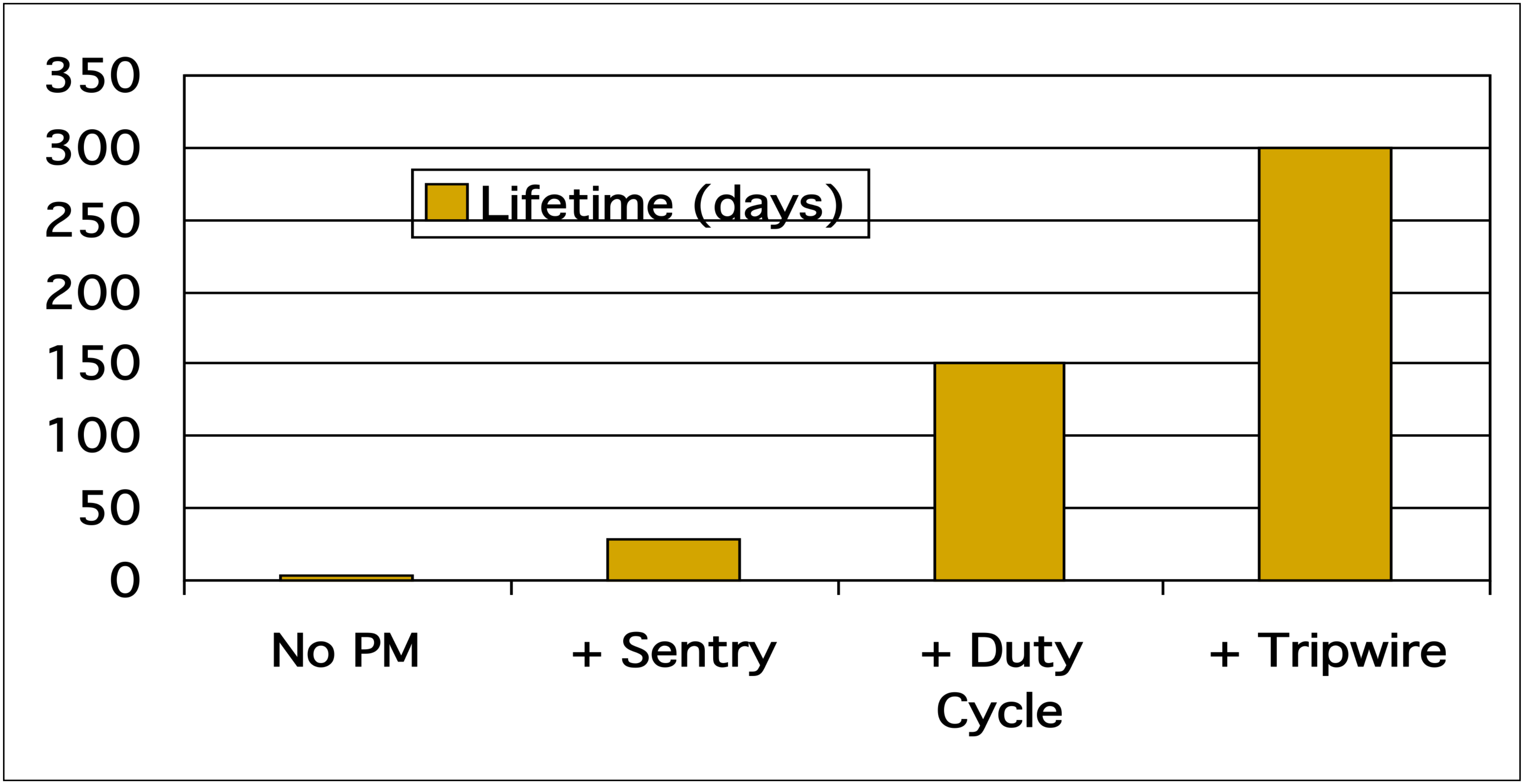


Evaluation Methodology





Evaluation Results: Lifetime



Evaluation Results: Target Detection and Classification

- Average detection delay: 2.42 seconds.
- Average classification delay: 3.56 seconds.
- Classification of humans, humans with weapons, and vehicles.
- Average delay to get velocity estimation: 3.75 seconds (average error: 6%).

Summary

- Successfully integrate 3 power management strategies into real surveillance system having a 10 months lifetime (source code available online).
- Analytical model to predict system performance under various system configurations.
- Simulation results exposing tradeoffs between detection performance and lifetime of the network.