Requirements for Quick Network Construction Mechanisms for the On-Site Emergency Rescue Activity

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Background

- Increasing threats of natural disasters in urbanized cities
- Increasing threats of artificial disasters, like terrorism in crowded parts of a city
- High risk to get into collapsed structures

Current Status

- Remote rescue operation using robots is intensively being researched
  - e.g. http://www.rescuesystem.org
- Investigation of disaster areas using a robot controlled by a human operator

Ex. Crawler Robot

- A robot with many crawlers
- Each crawler is connected by a joint with high degree of freedom
- Can get over obstacles in disaster areas

Problems

- Most of the robots are designed to be controlled by a simple remote control method (e.g. with a wired remote)
  - The range that the robot can move around is limited by the range of the remote
  - An operator must get into the disaster area with the robot to control it, that may cause a secondary disaster

Goals

- Robohoc Network
  - The ad-hoc mesh network for rescue robots operation
  - Providing extended reachability of robots, without imposing any risks on robot operators

Target Environment

- Disaster model: Urban disaster
  - Collapsed structures
  - Narrow paths
  - Possible secondary disasters
- Frontier size: About 73,000m^2 (Reference: Yaesu Underground Mall)
  - Limited wireless reachability
  - Possible wireless interference

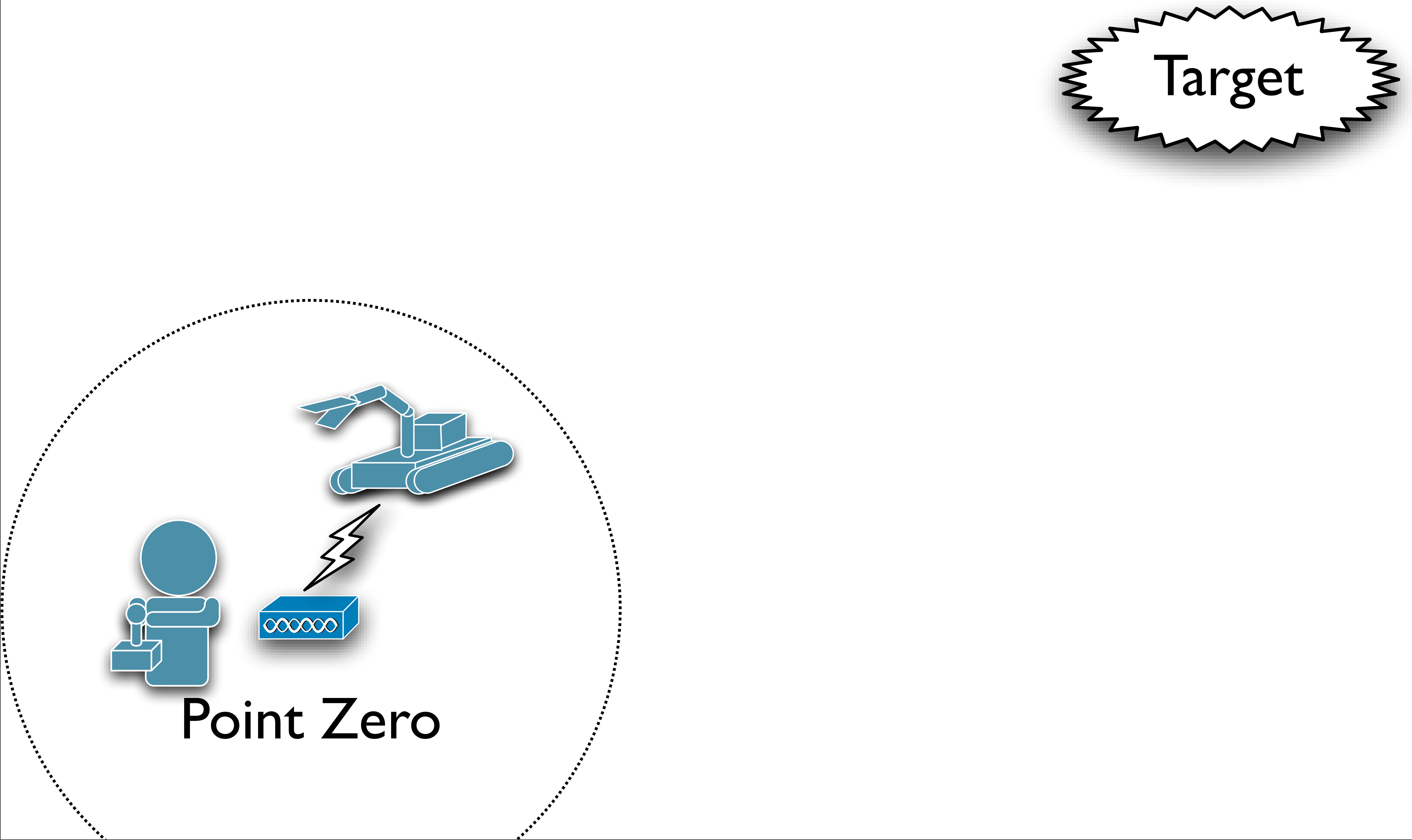
Key Features

- Automatic network construction
- Recovery from partitioning
- Quality assurance
- Scalability
- Robust commucication

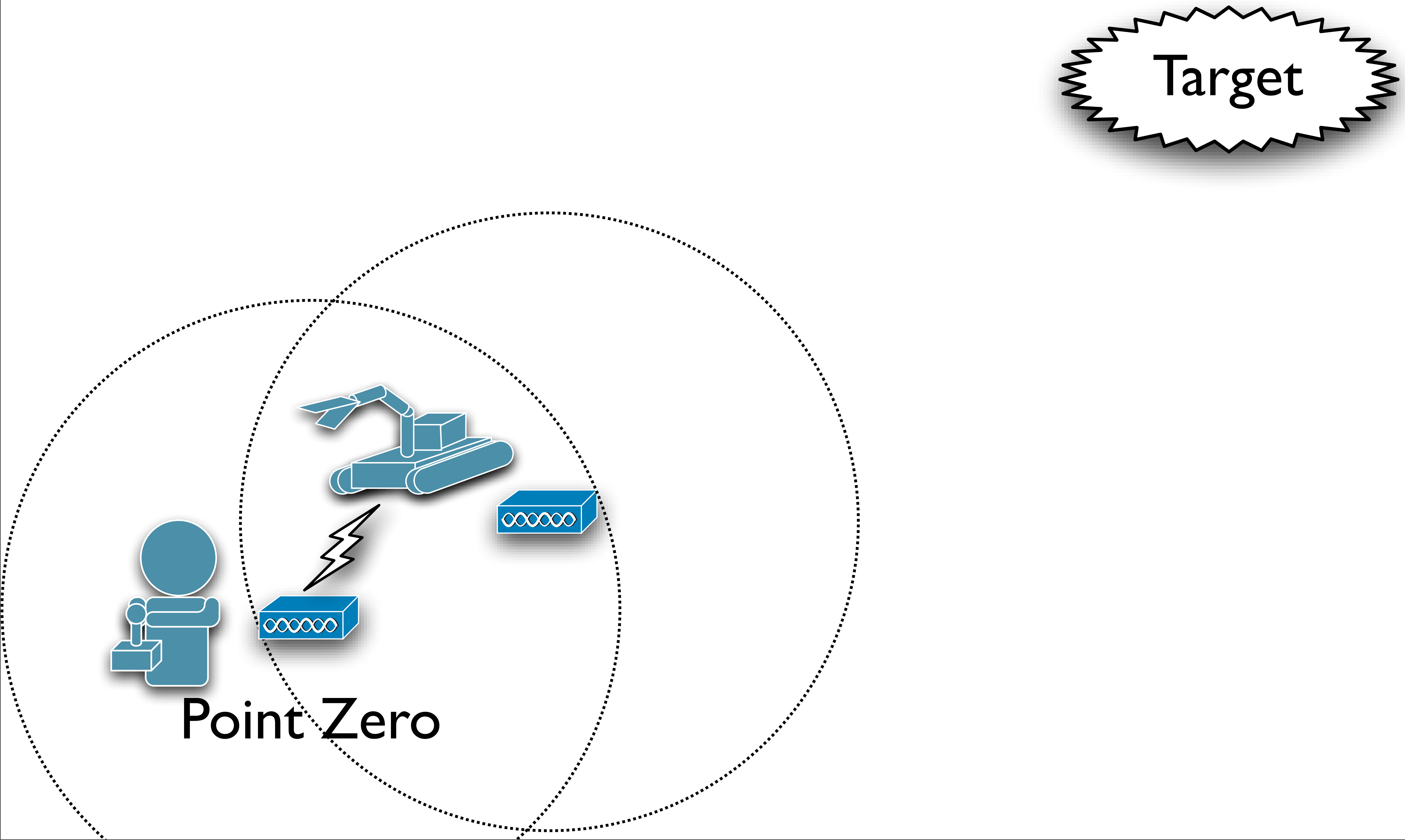
Robohoc Construction

- The backbone network is constructed by multiple wireless access points (APs)
- Each AP has its local subnet
- A robot connects to one of the APs
- Robots put new APs to extend the network

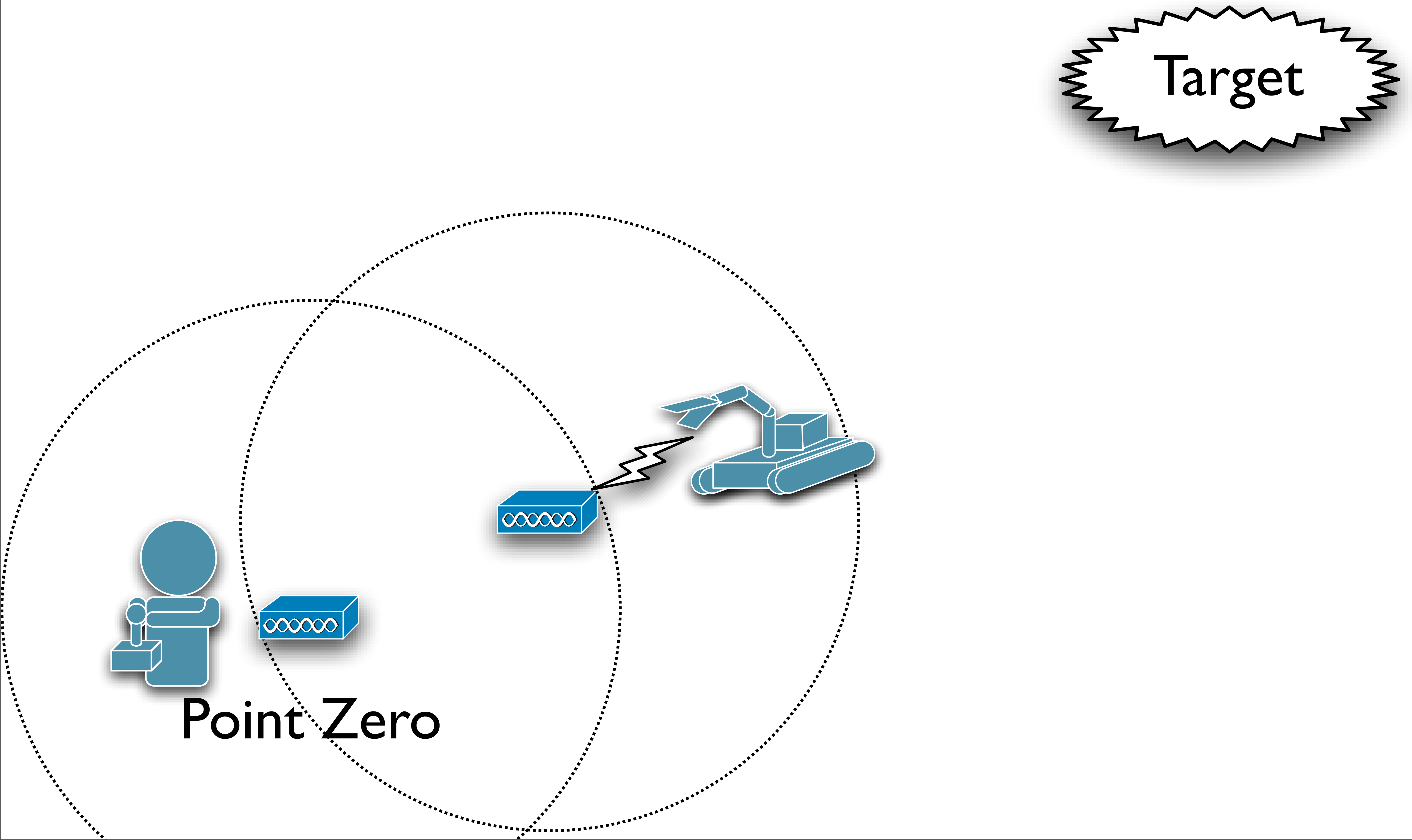
Basic Operation



Basic Operation



Basic Operation



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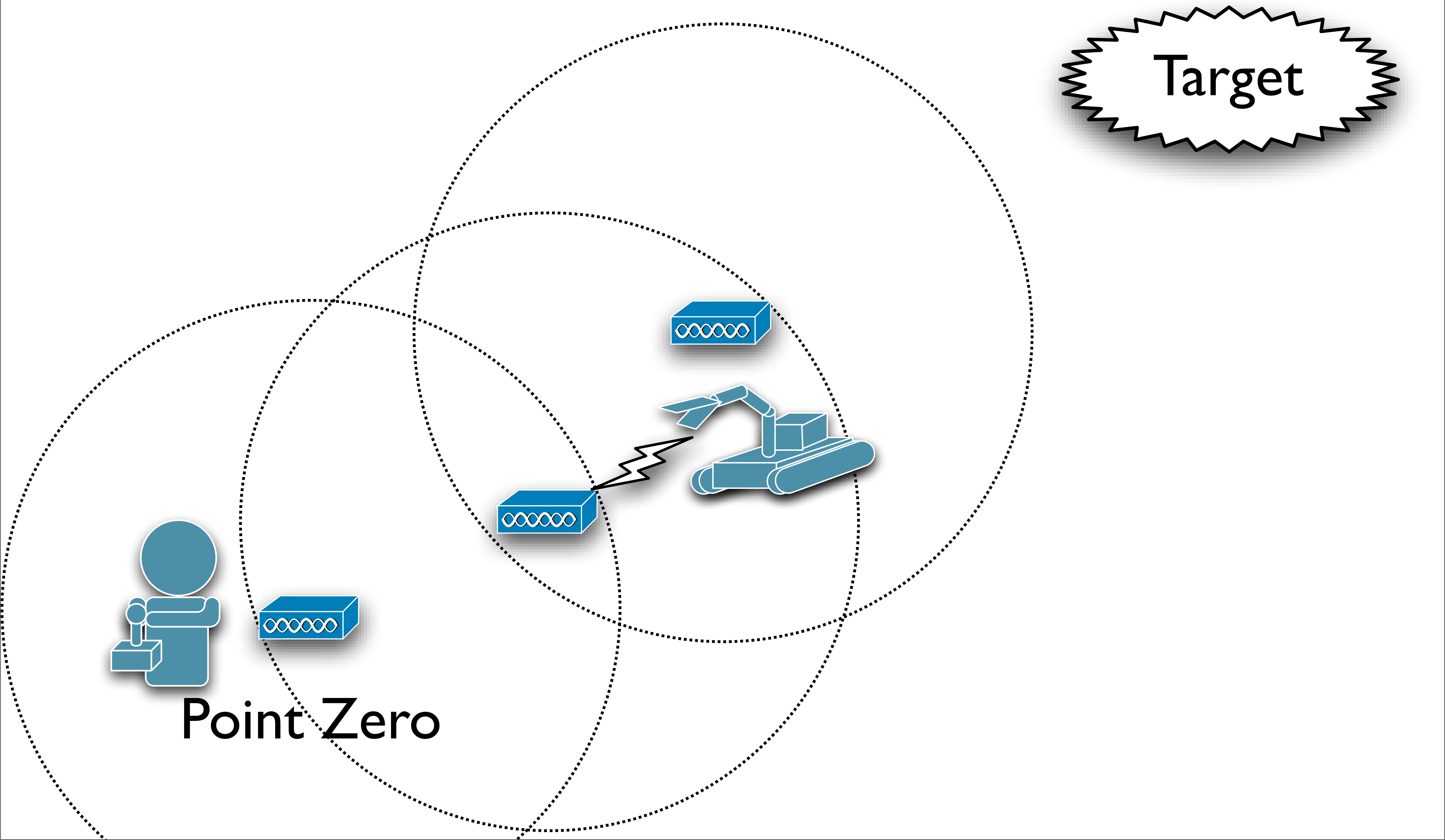

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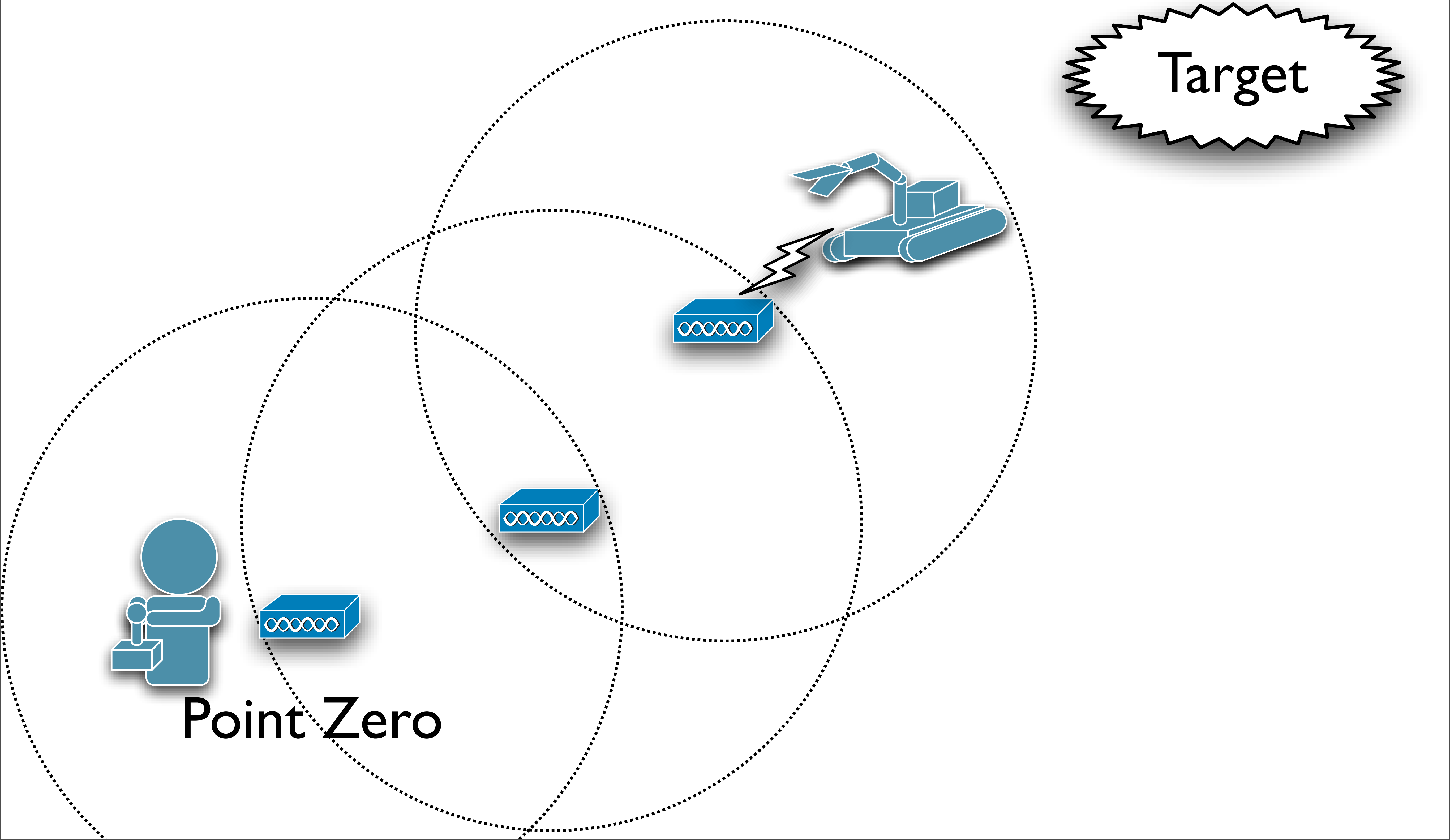
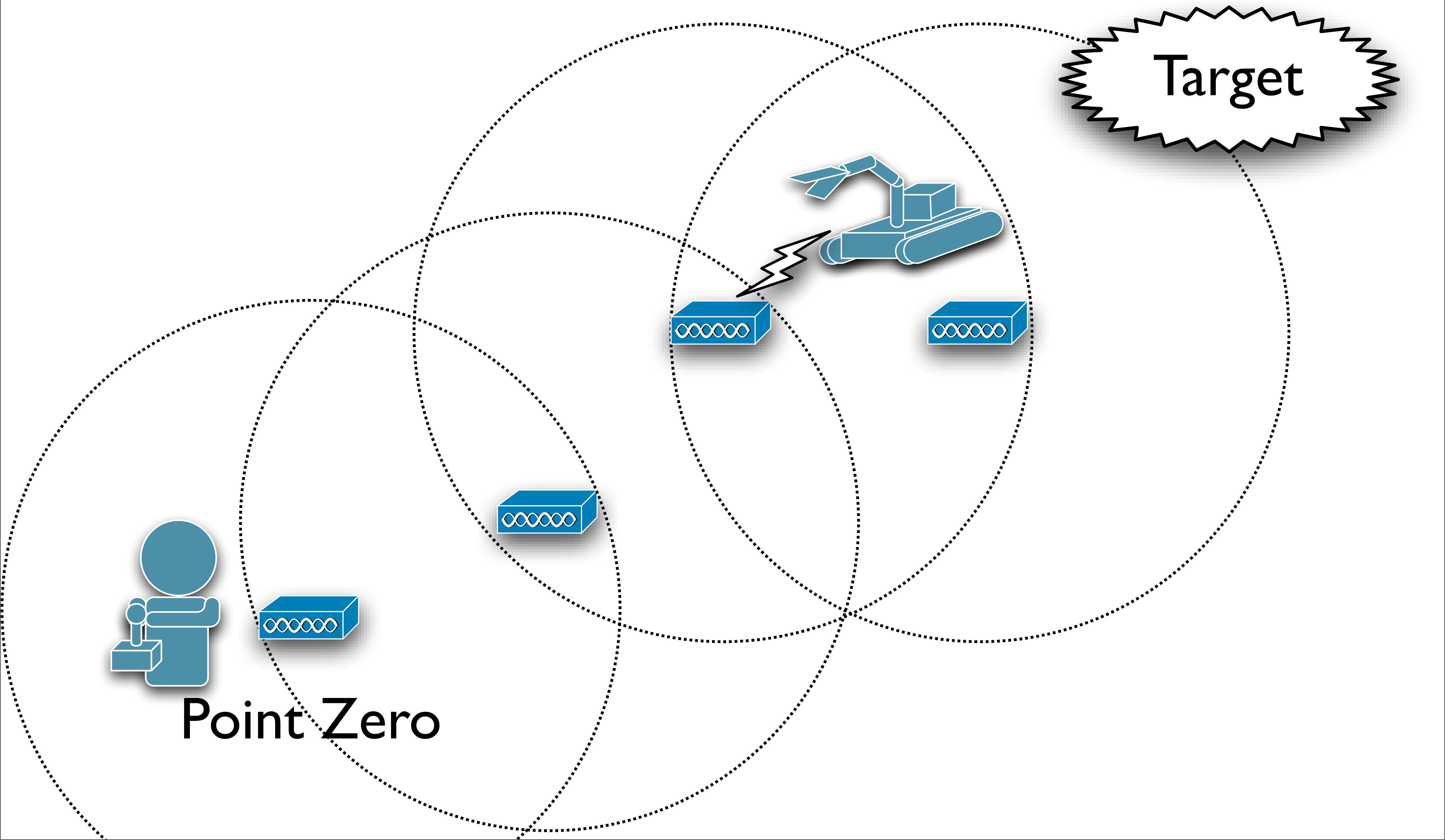


Basic Operation



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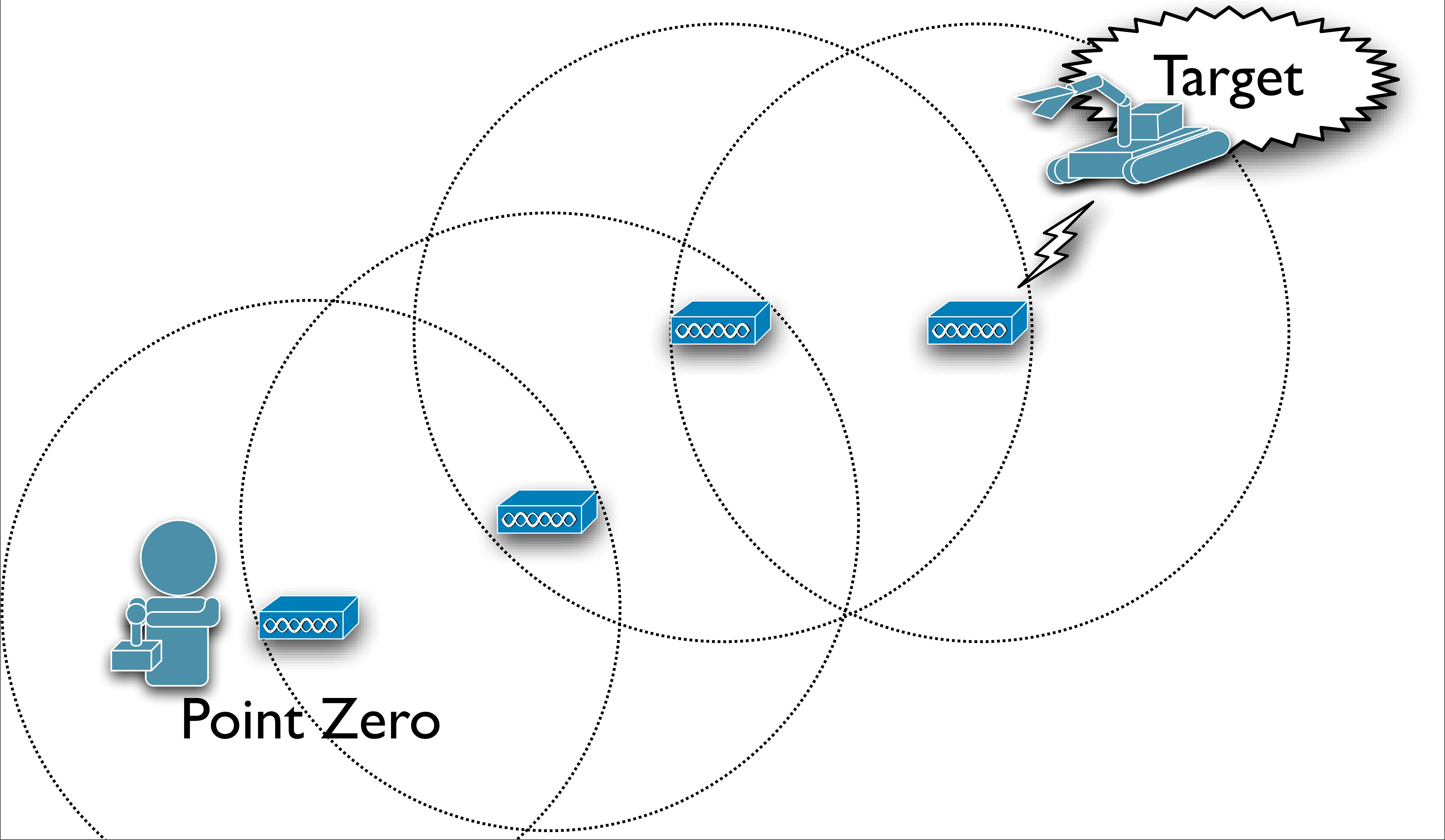

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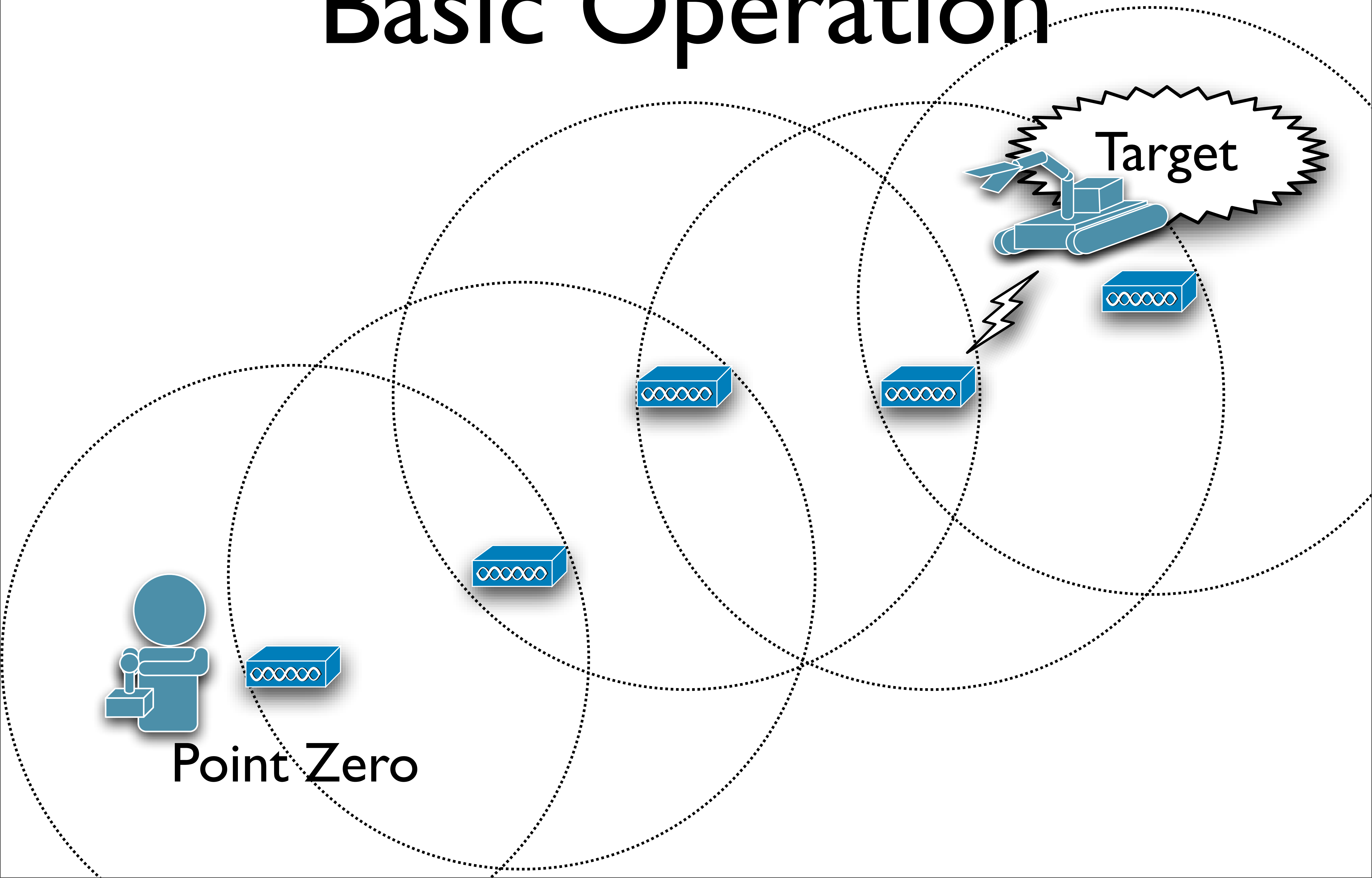
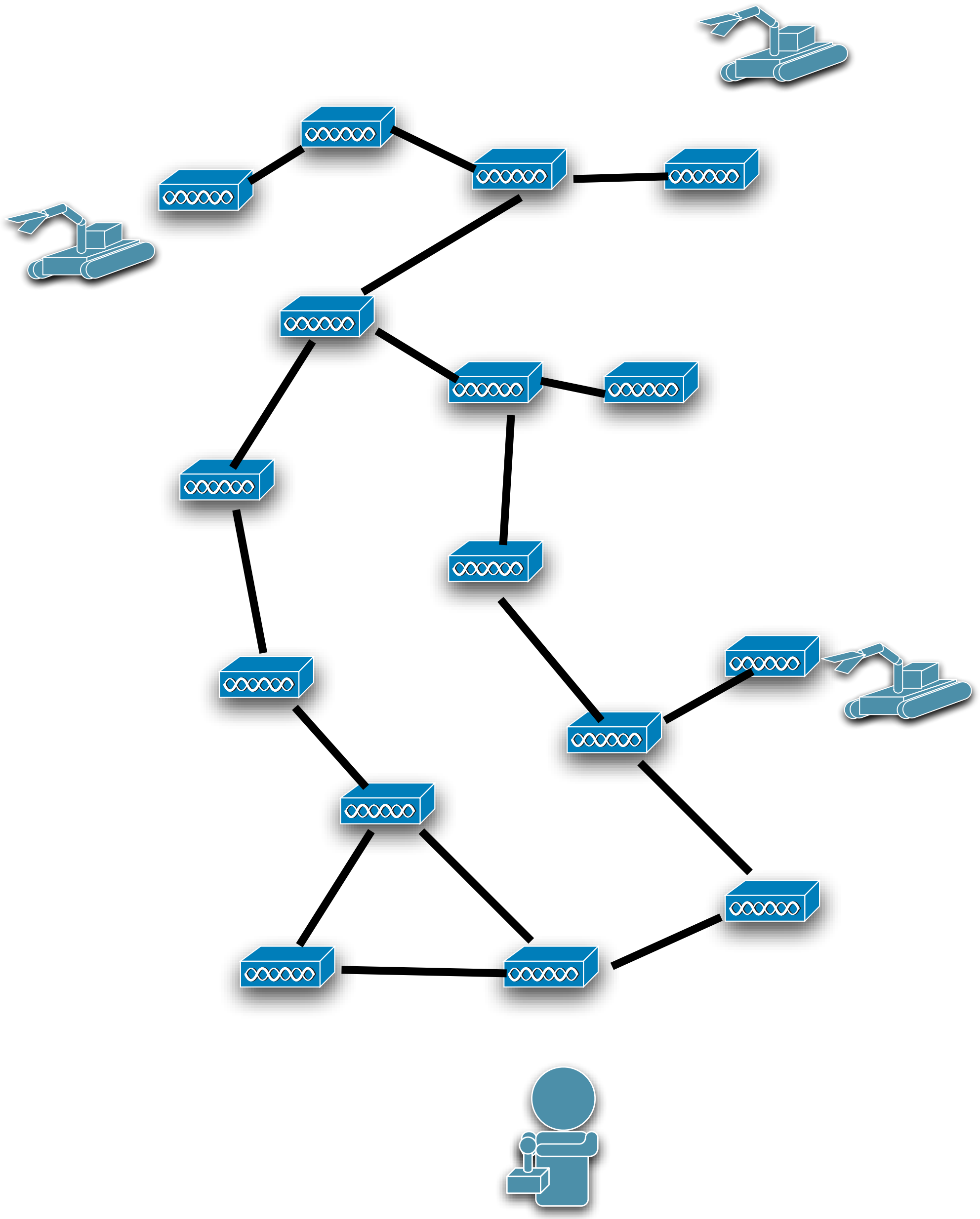


Partitioning and Recovery

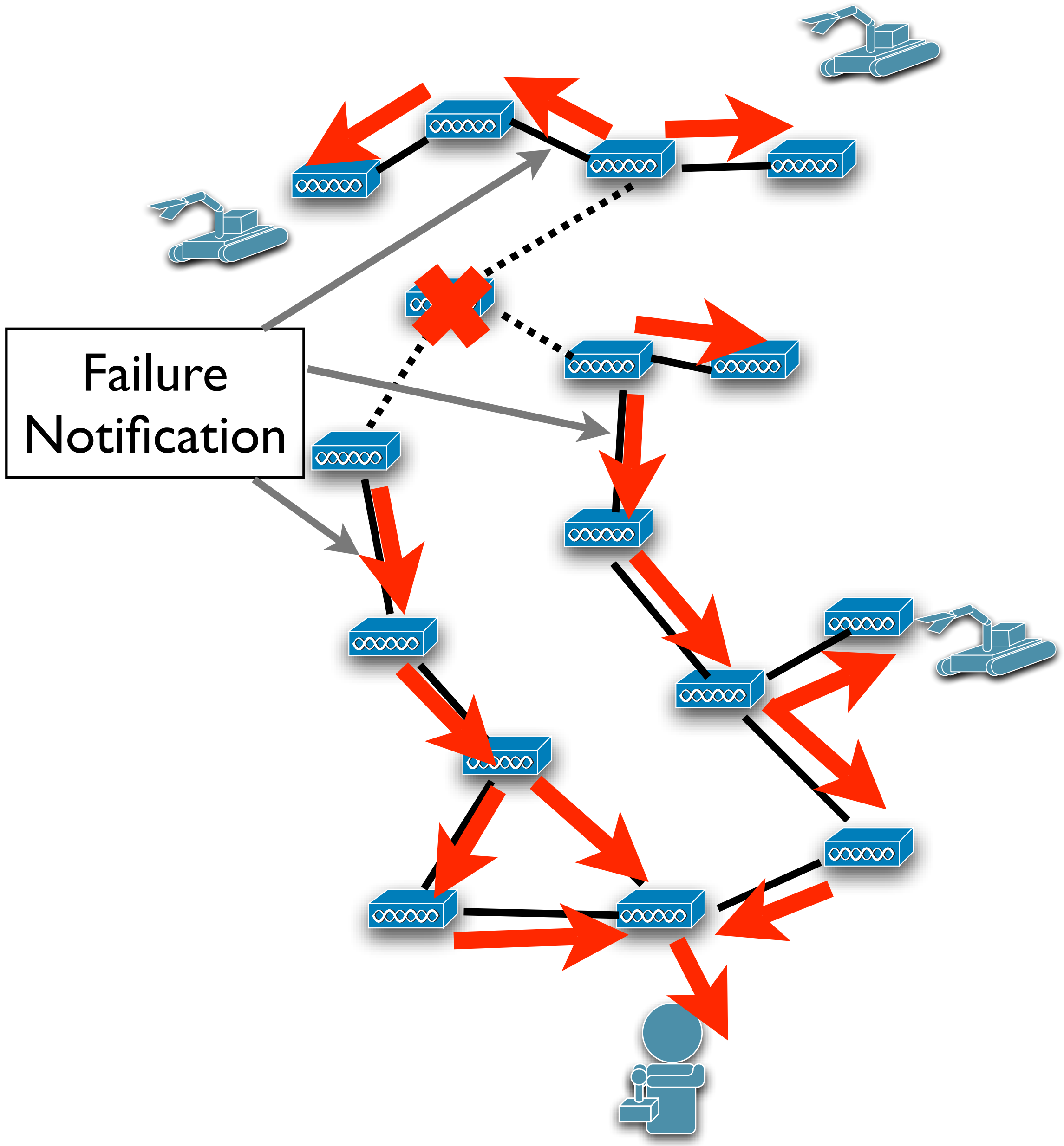
- The Robohoc network must have redundant paths in case of AP failure

- However, it is not always possible to recover from failure using redundant routes



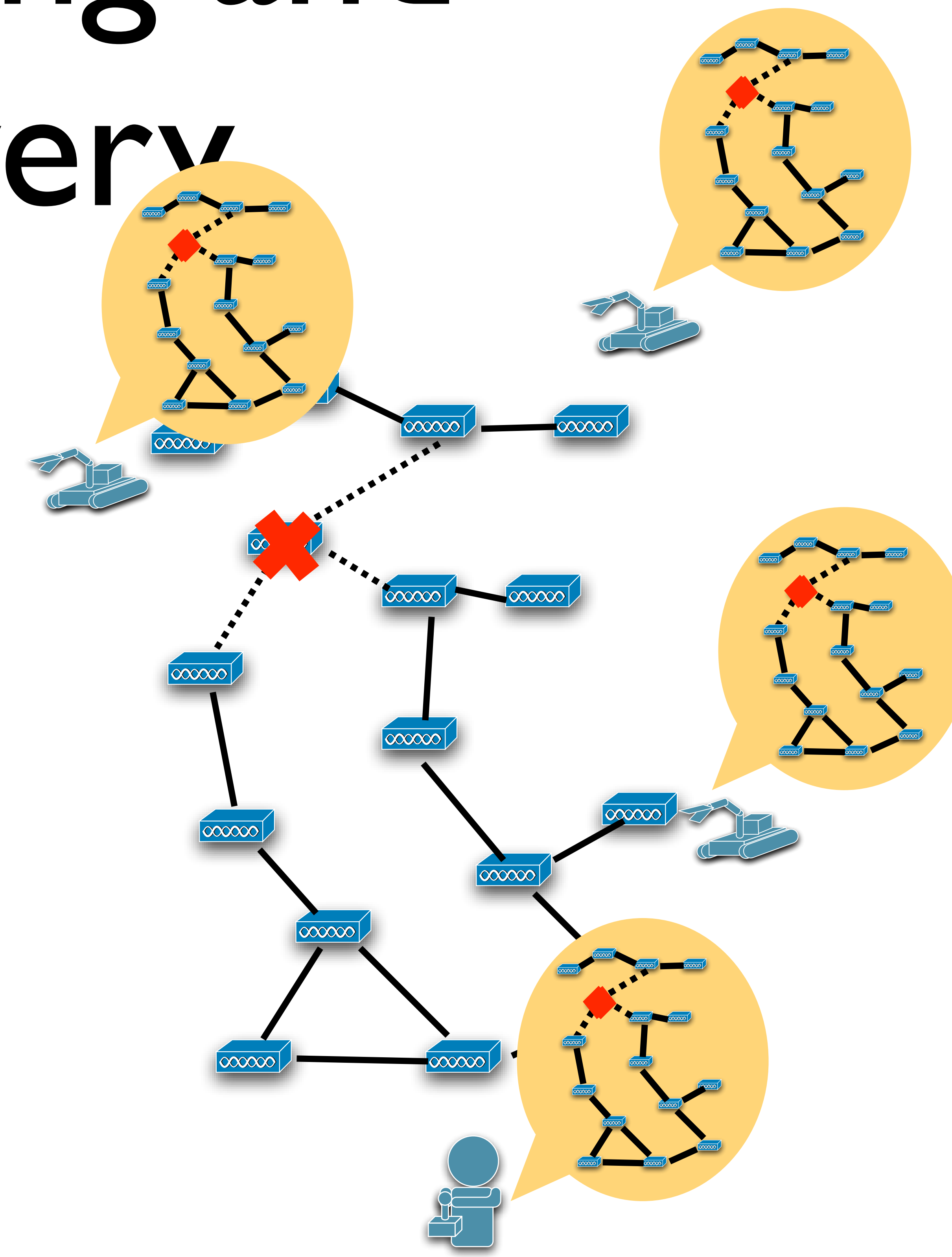
Partitioning and Recovery

- To recover from failure, a new AP has to be added to recovery point
- Topology information sharing is needed to find the proper location of the new AP



Partitioning and Recovery

- Some robots may leave from operator's control
- Manual recovery attempt if the operator has robots
- Automatic recovery attempt if no robot is under control



Quality Assurance

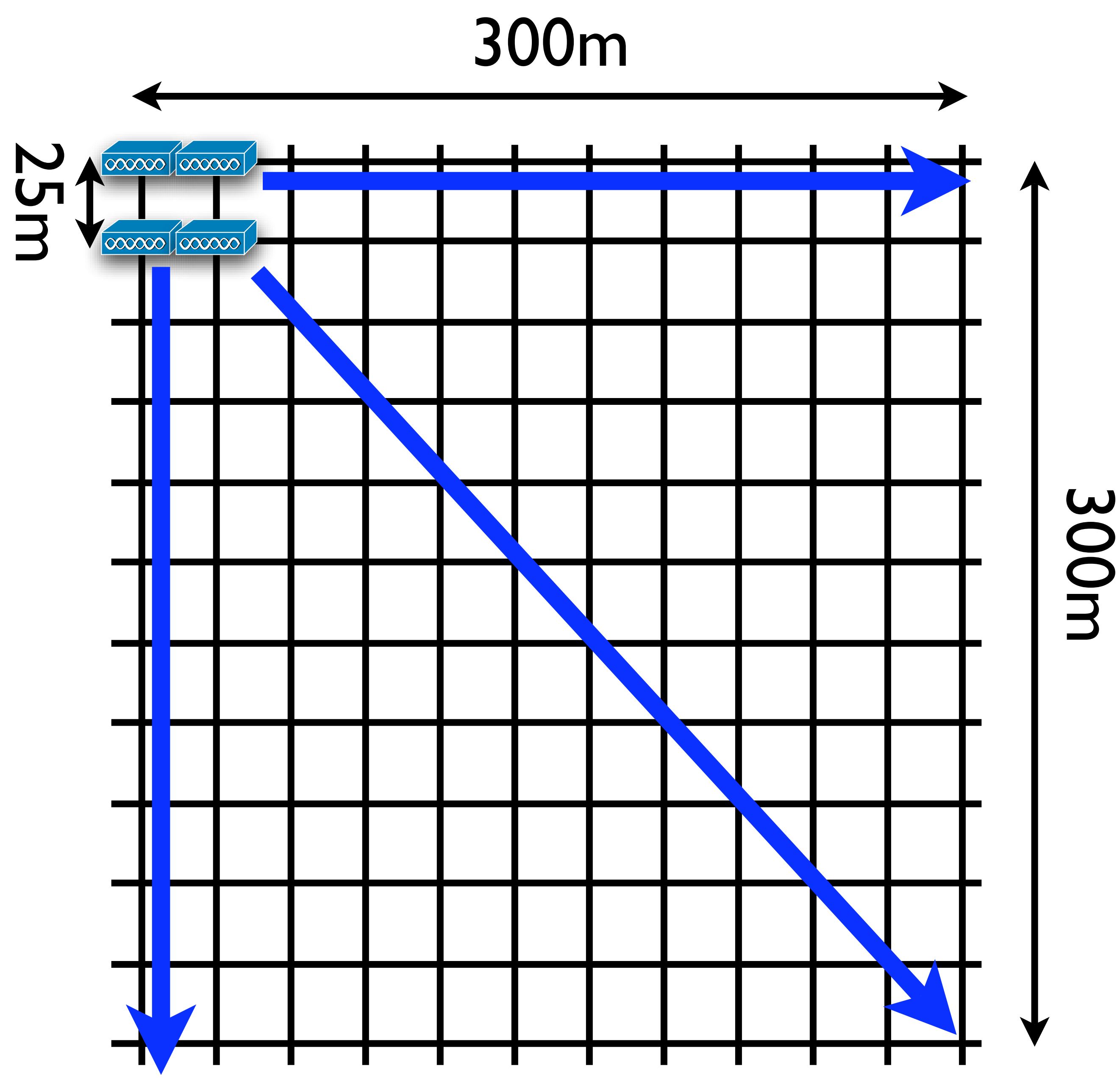
- Real-time control requires 1-second communication delay at maximum
  - It is impossible to guarantee in the Robohoc network
- Predictive control can be done with fixed delay and jitter network
  - c.f., T. B. Sheridan, "Space Teleoperation Through Time Delay: Review and Prognosis," IEEE Transaction of robotics and automation, Vol.9, No. 5, pp.592–606, October 1993.

Quality Assurance

- Type of Service support is necessary
  - Robot control traffic requires
    1. Low latency communication when controlled in real-time
    2. Constant delay and jitter when controlled by the predictive control method
  - Topology information traffic will require low bandwidth and can live with high delay
  - Video streaming require high bandwidth and can live with high delay

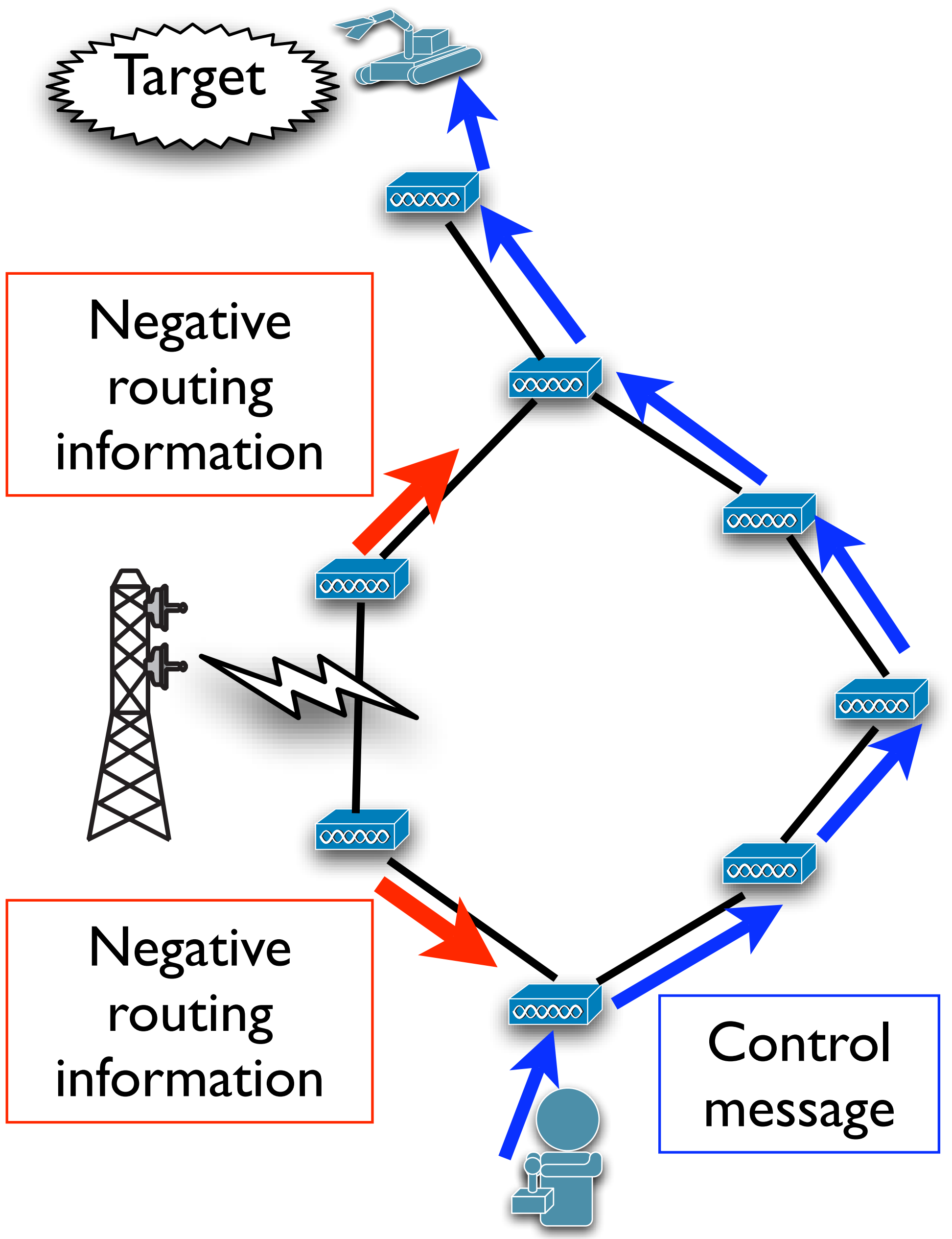
Scalability

- Reference mall: Tokyo Yaesu Underground Mall (about 300m x 300m)
- Wireless coverage is about 50m (802.11a case, without any obstacles) or less
  - Assuming we can reach 25m, we need 144 nodes to cover entire area
  - Hop counts are 24



Wireless Radio Interference

- Routing algorithm must take the link quality into account
- In the disaster area, there may be existing wireless devices that are not used any more and interferes the Robohoc connection



Requirements Matrix

AP distribution	RHRs and robots cannot be located uniformly. The Robohoc network must support the non-flat node distribution. (Section 3.1)
Communication distance	The distance between teleoperators and robots is from a few hundreds meters to about 1 kilometer. (Section 3.2)
Network partitioning	The Robohoc network may be partitioned while constructing the network or operating rescue activities. The network must have a property to recover from partitioning. (Section 3.3)
Real-time robot control	For real-time robot control, the network latency has to be less than 400ms. Robots can be controlled even the latency is more than 400ms using how- ever, in that case, the latency has to be predictable and stable. (Section 3.4)
Type of service support	The Robohoc network must be able to provide different traffic properties for different contents, for example, the real-time delivery for the robot control and the wider bandwidth for the live streaming. (Section 3.4)
Topology information sharing and storing	When recovering from partitioning, teleoperators, APs and robots have to know the topology of the network to find the failure point. The topology information must be shared and stored in every node. (Section 3.6)
Bootstrap and auto-configuration	The network construction and rescue activities must be started as soon as possible. Every node must start with minimum manual configuration and must have an auto-configuration property. (Section 3.7)
Hop counts	The number of RHRs in a Robohoc network may be more than 100. The average hop count in this case would be more than 20. To support a wider area, the number of hops and average hop count will increase. (Section 3.8)
Layer 2 information utilization	The Robohoc network uses a wireless communication media to create the network. Each RHR has to monitor the link quality of their connections and utilize the information for better performance. (Section 3.9)
Fault Tolerance	The Robohoc network must not have a single point of failure. The network must be able to recover from partitioning either by the human intervention or by autonomous recovery actions of robots. (Section 3.10)

Conclusion

- Demand for a new type of network service for operating investigation robots in disaster situation
- A dynamically extendable ad-hoc mesh network *"Robohoc Network"* is proposed
- Examined requirements for the Robohoc Network and defined necessary functions

Future Plans

- Define the suitable routing algorithm for the Robohoc Network
- Prototype routers for access points
  - Validation of routing algorithms in a dynamic mesh network and performance measurement
- Integration with robots
- Field test