

A Software Framework for Mobile Ad hoc Data Communications Using Voice-Centric Tactical Radios



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Motivation

- State of Practice: Modern C2 capabilities often don't reach front line troops
 - situation awareness still voice centric
 - transition to information centric operation limited by legacy stove-pipe system designs
- State of Art: Mobile ad hoc networking is becoming a commodity technology in the civilian sector
 - ubiquitous high speed access to multimedia
 - minimum configuration



Research Objectives

- Investigate feasibility of providing data networking capability to small units with legacy radios
- Minimize requirement for additional “networking hardware”

Proof of Concept via SINCGARS Radio





System Components

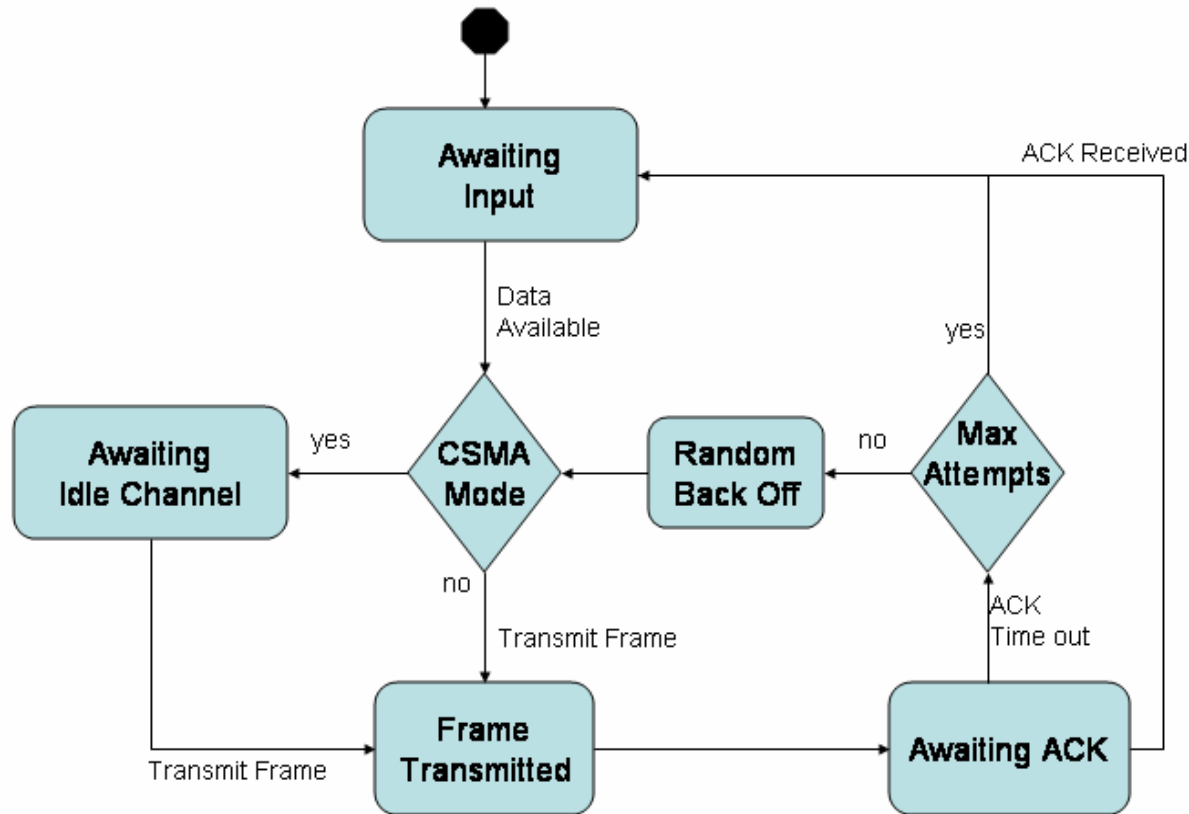
- Data Link Protocol
- Multi-hop Routing Capability
 - Expected Relative Positioning Routing with Congestion Avoidance (ERP/CA)
- Tactical Chat Application
 - SINCGARS Data Demo



Data Link Protocol

- Media Access Control
 - ALOHA & CSMA Functionalities
- Flow Control and Error Control
 - Simple Stop-and-Wait
- “802.11-Lite”
 - Minimum subset of 802.11 features
 - MAC, Encapsulation, Error Control
 - No sync, beacons, probes, NAVs, authentication, etc.

Media Access Control





ERP/CA Routing Protocol

- Operation-aware
 - Exploit Operational Knowledge about Node Movements
- Bandwidth-Efficient
 - Minimize Overhead of Control Traffic



Operational Knowledge

- TTPs (Tactics, Techniques, and Procedures) Used by Tactical Units
 - Military formations
 - Wingman concept
- Unit Leaders Maintain Physical Proximity
 - Maintain Radio Contact
 - Facilitates Command and Control



Operation-aware Routing

- Route Selection Based Upon Relative Positions of Nodes Within Formation
 - Relative positions between nodes (or node relationships) are policy-driven
 - Links between nodes with “close” relationship tend to be persistent
- Mechanism: Nodes wait for a period of time before responding to route request
 - Node with closest relationship to destination responds to route request first



Route Response Wait Formula

$$RRW = CW + CAV + IRW \quad \text{milliseconds}$$

CW values:

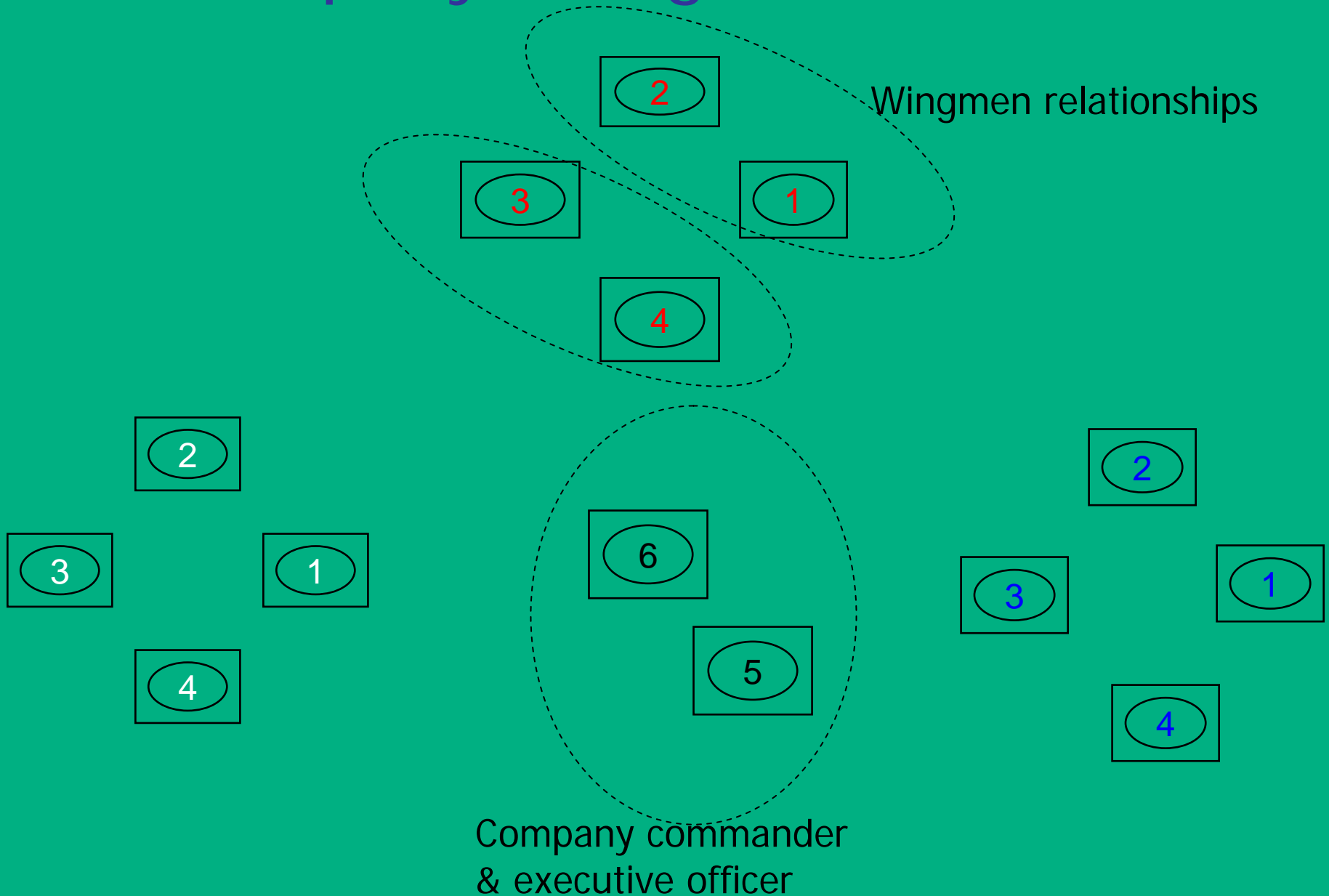
Relationship Category	Wait Time Assigned (ms)
GOOD	1500
BETTER	1000
BEST	500
DIRECT LINK	0



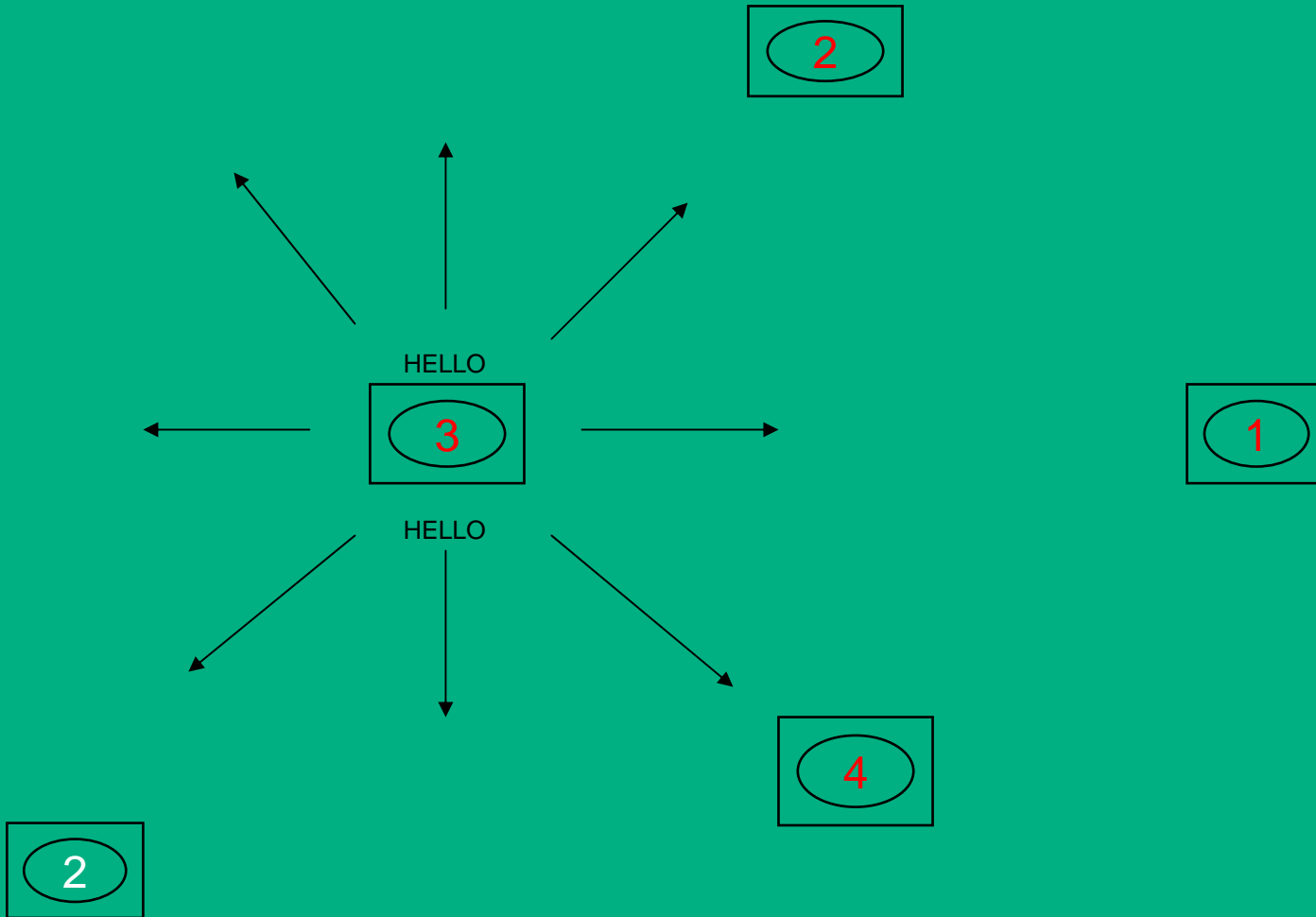
Bandwidth-Efficient Routing

- On-demand Route Discovery
- Controlled Flooding
 - Node stops flooding if it has route to destination
- Node Relationships are Input to Protocol
 - No need to discover them (**this is novel!**)

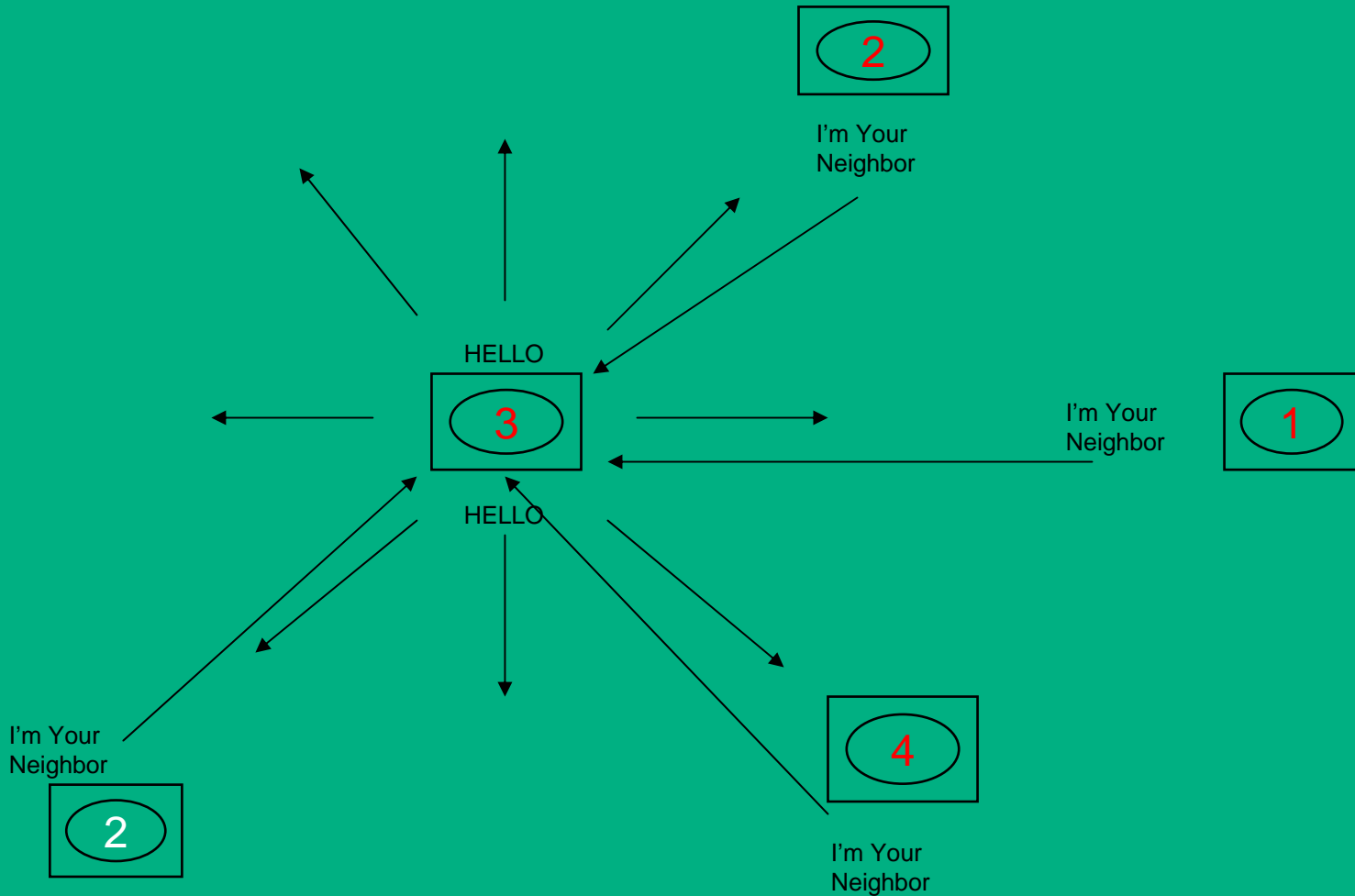
Tank Company Wedge Formation

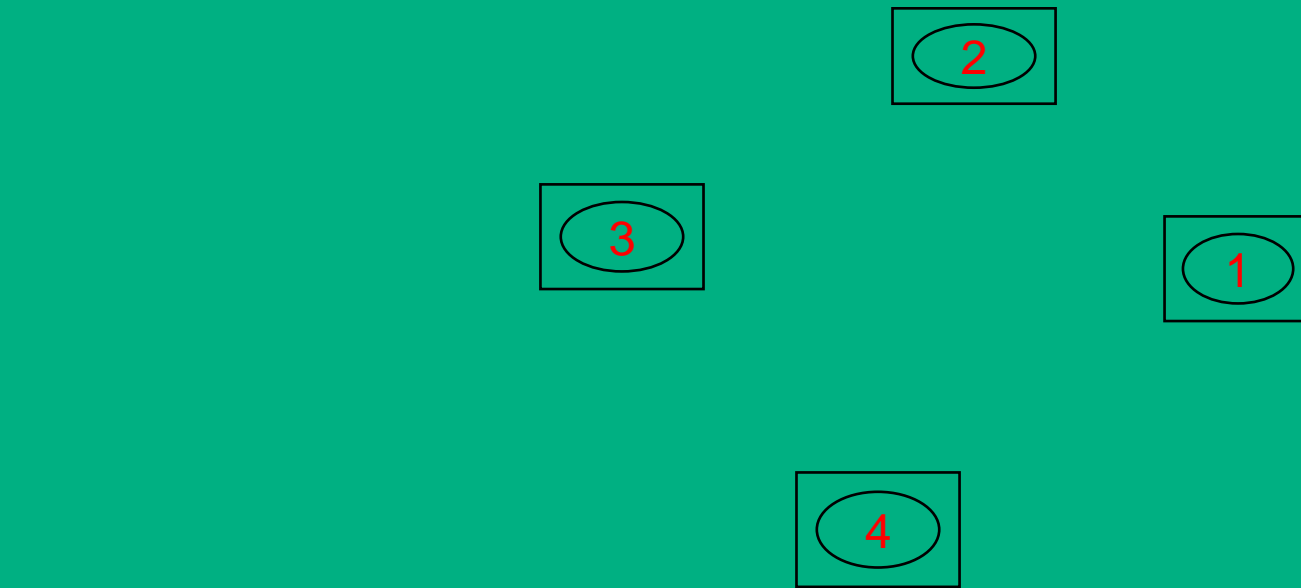


Neighbor Discovery

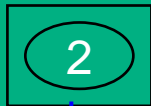


Neighbor Discovery (HELLO Response)



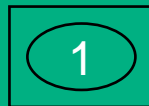
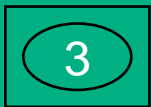


Source



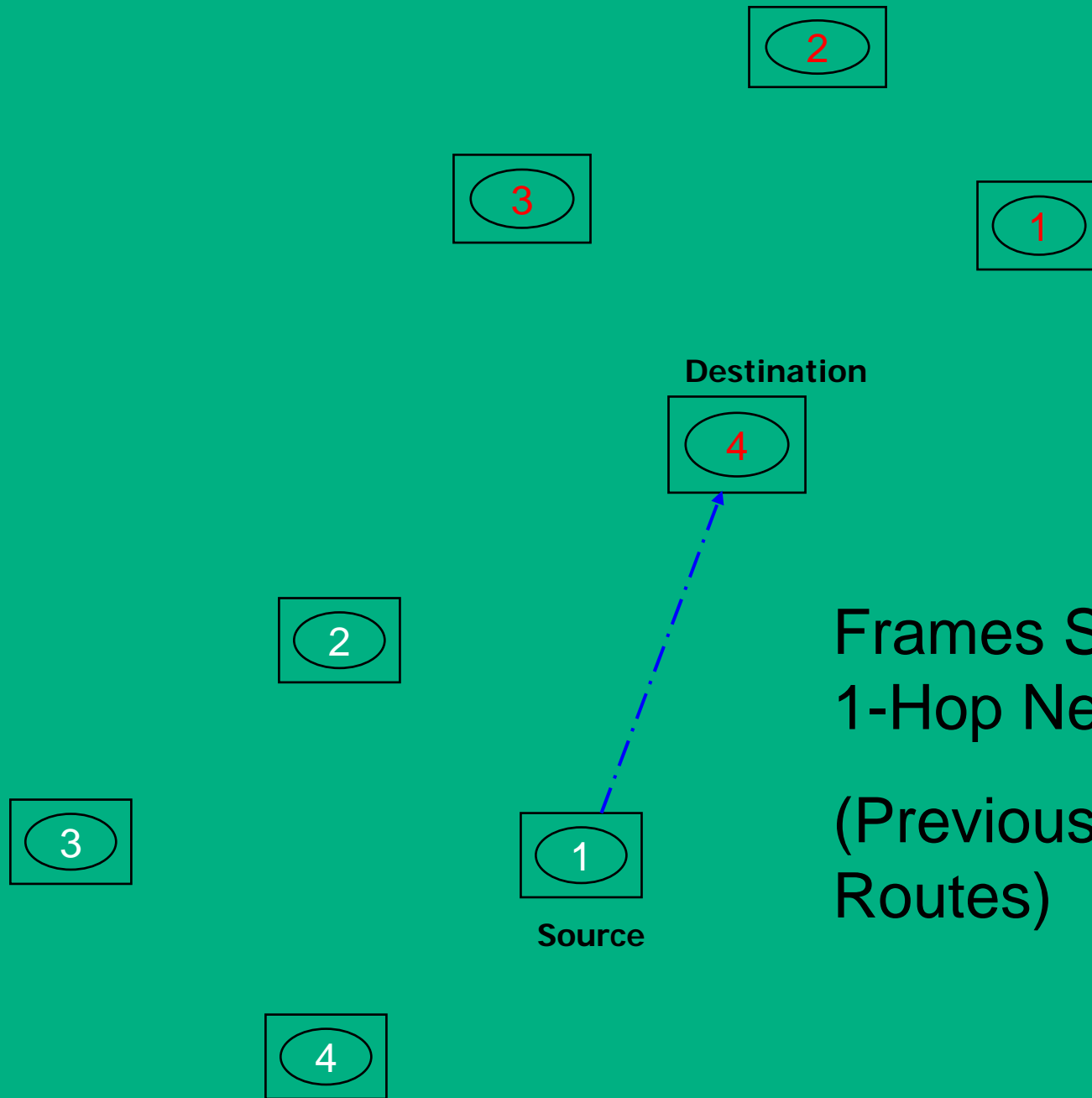
Frames Sent Between
1-Hop Neighbors

(Previously Known
Routes)

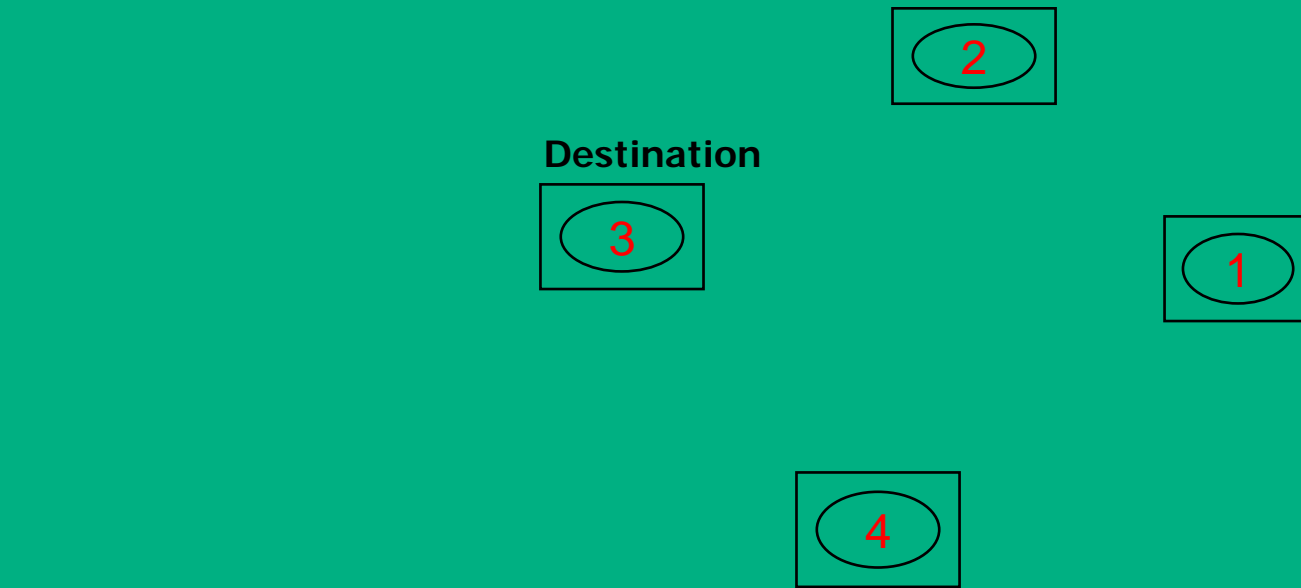


Destination



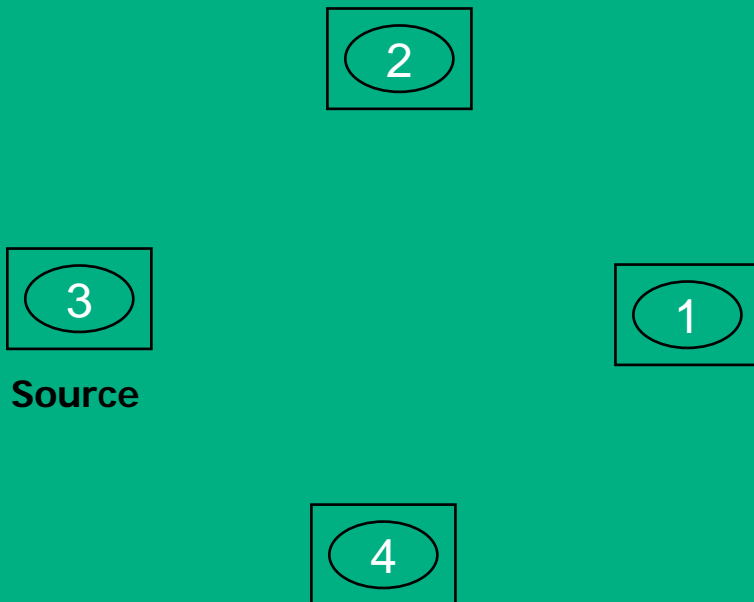


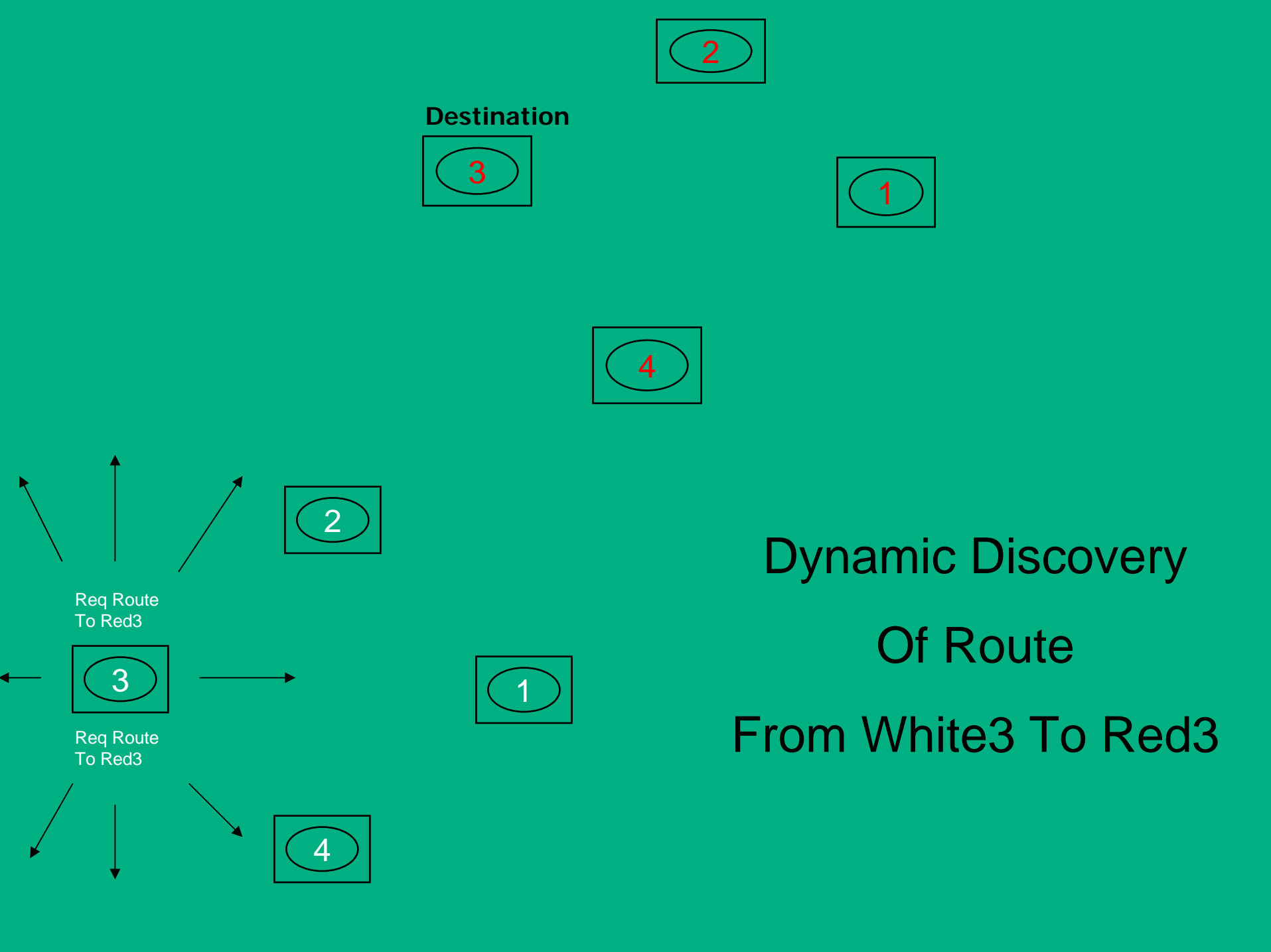
Frames Sent Between
1-Hop Neighbors
(Previously Known
Routes)

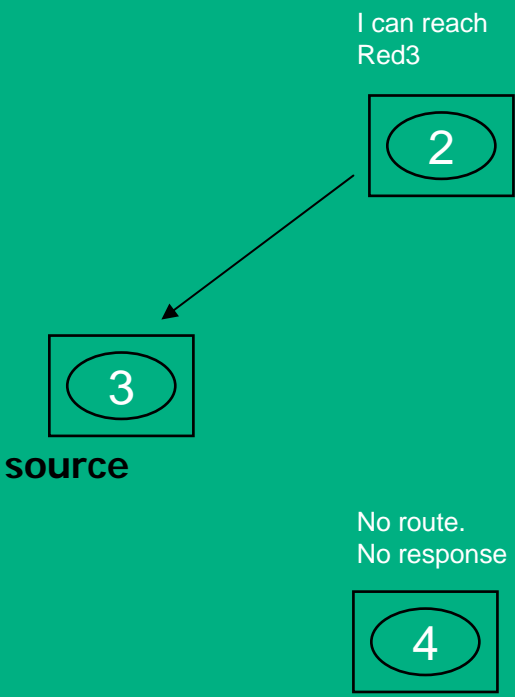
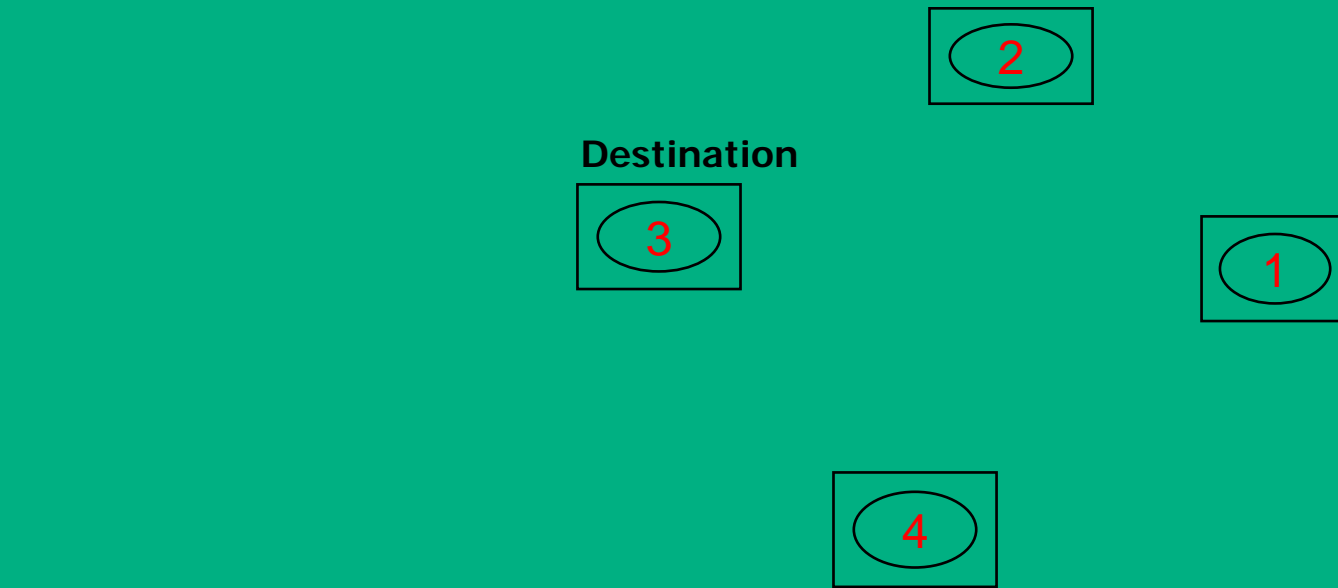


Frames Sent Between
Multi-Hop Neighbors

(Dynamic Discovery
Of Routes)



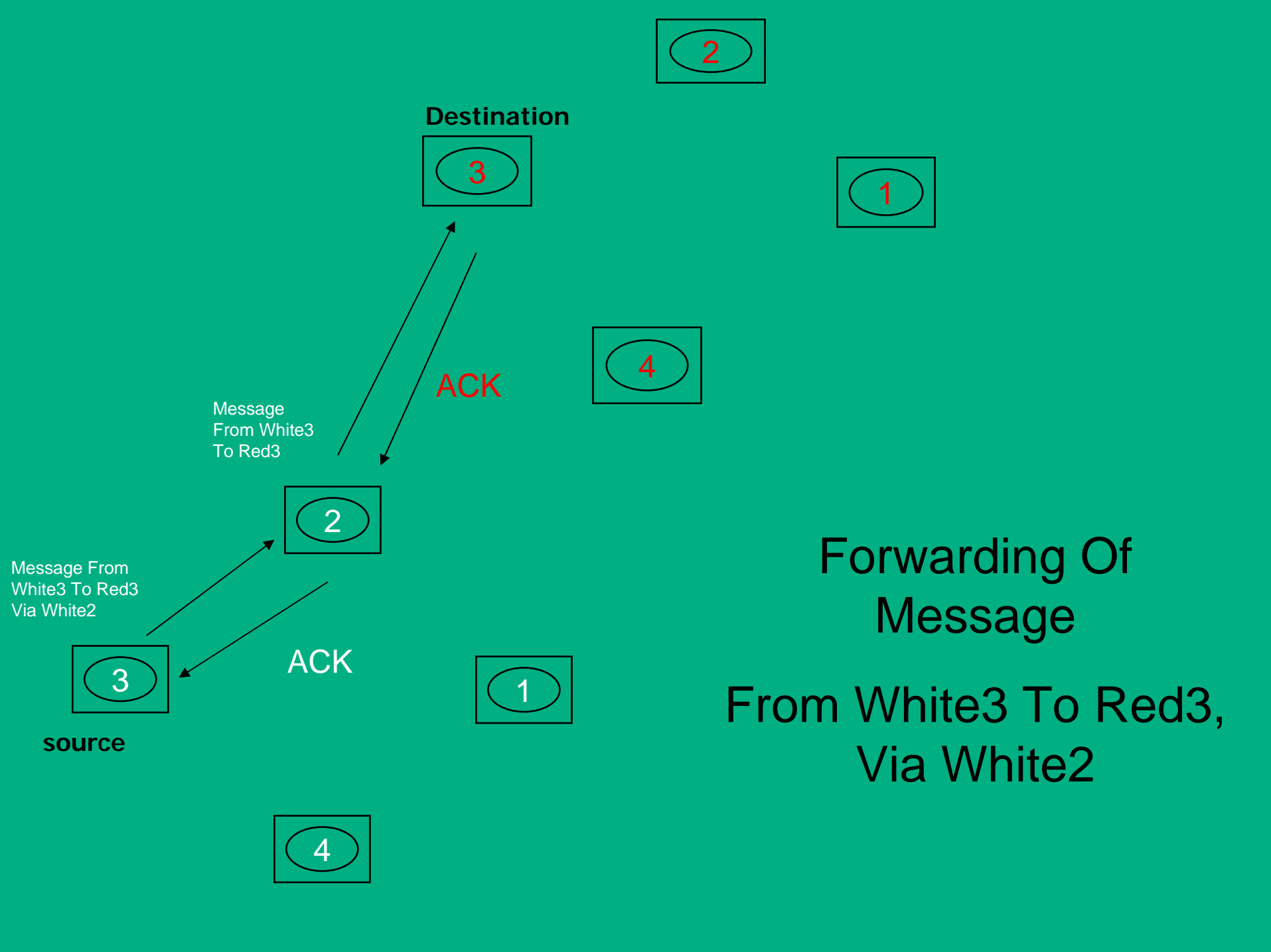




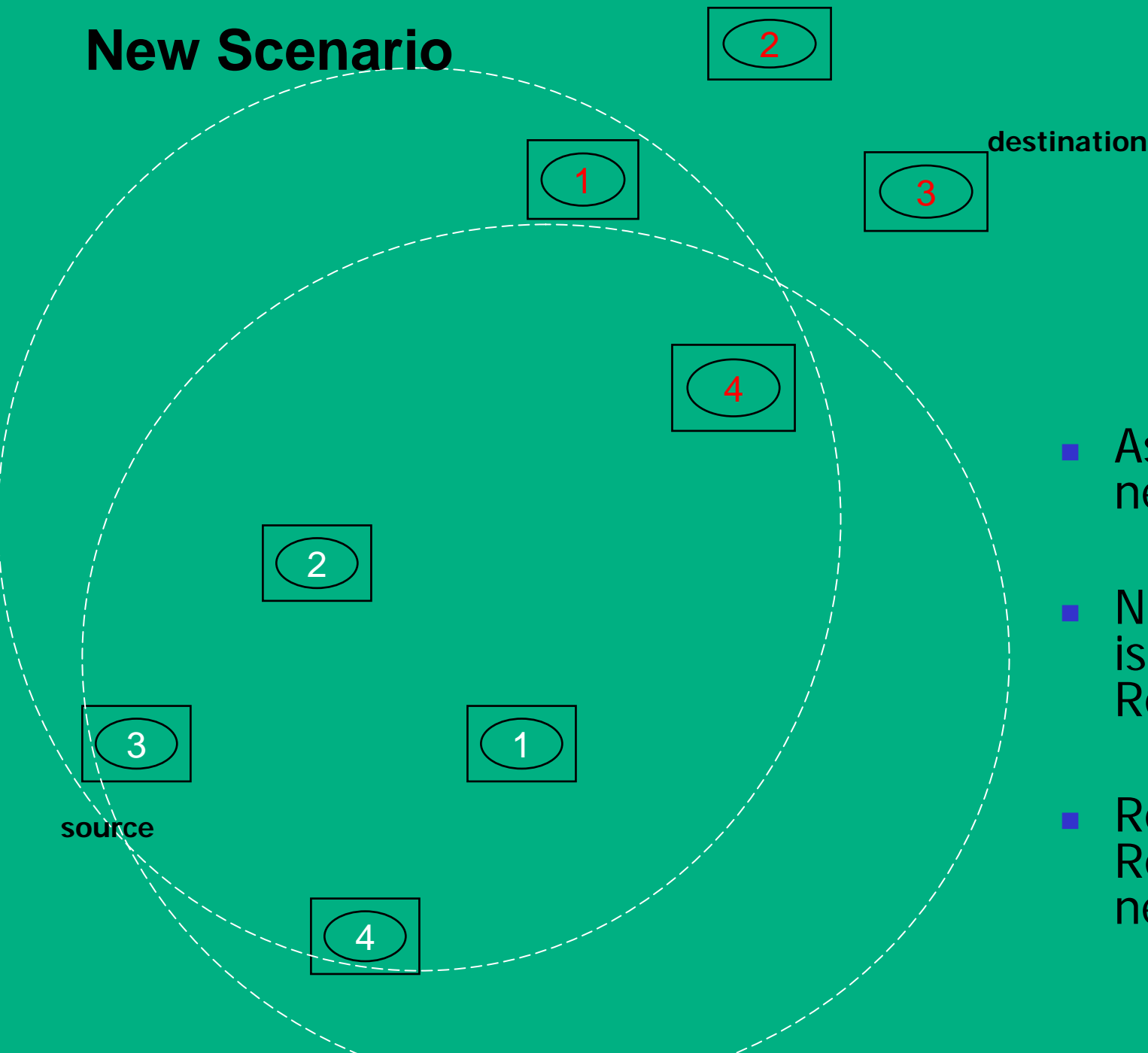
No route.
No response

No route.
No response

Dynamic Discovery Of Route From White3 To Red3

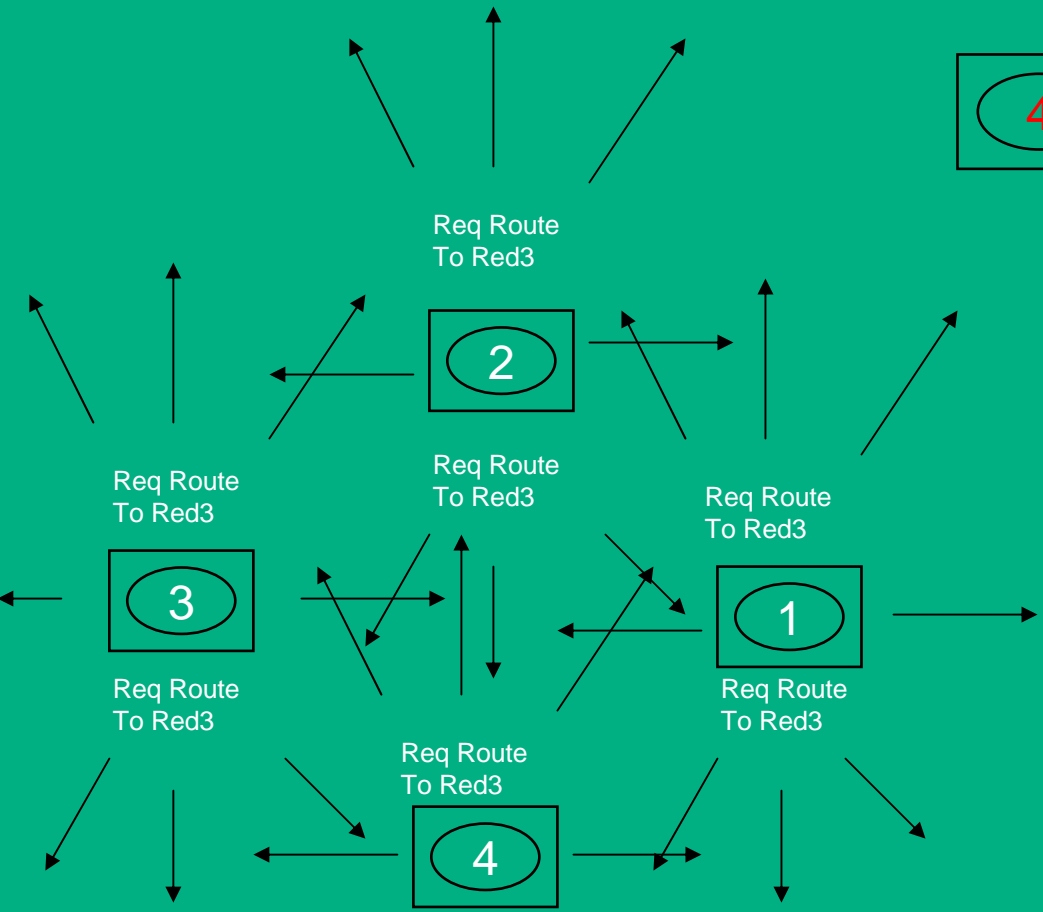
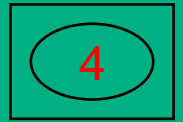
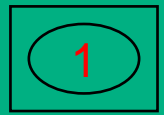
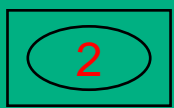


New Scenario



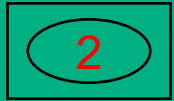
- Assume this new state:
- No white node is in range of Red3
- Red3 and Red1 are in new positions

Dynamic Route Discovery

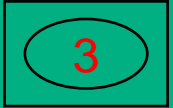


- Requests are broadcasted and flooded
- TTL limits life of flood
- Route response ends flooding

Response To Route Request

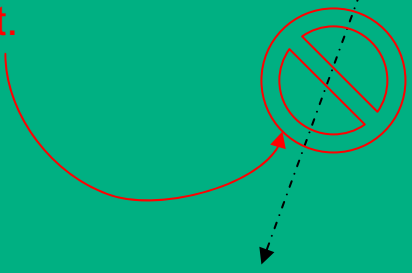
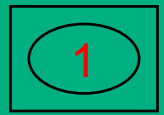


destination

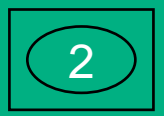
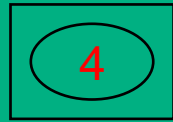


Not sent because Red4's response is heard first.

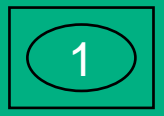
I can reach Red3



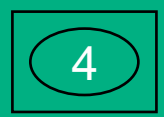
I can reach Red3



I can reach Red3



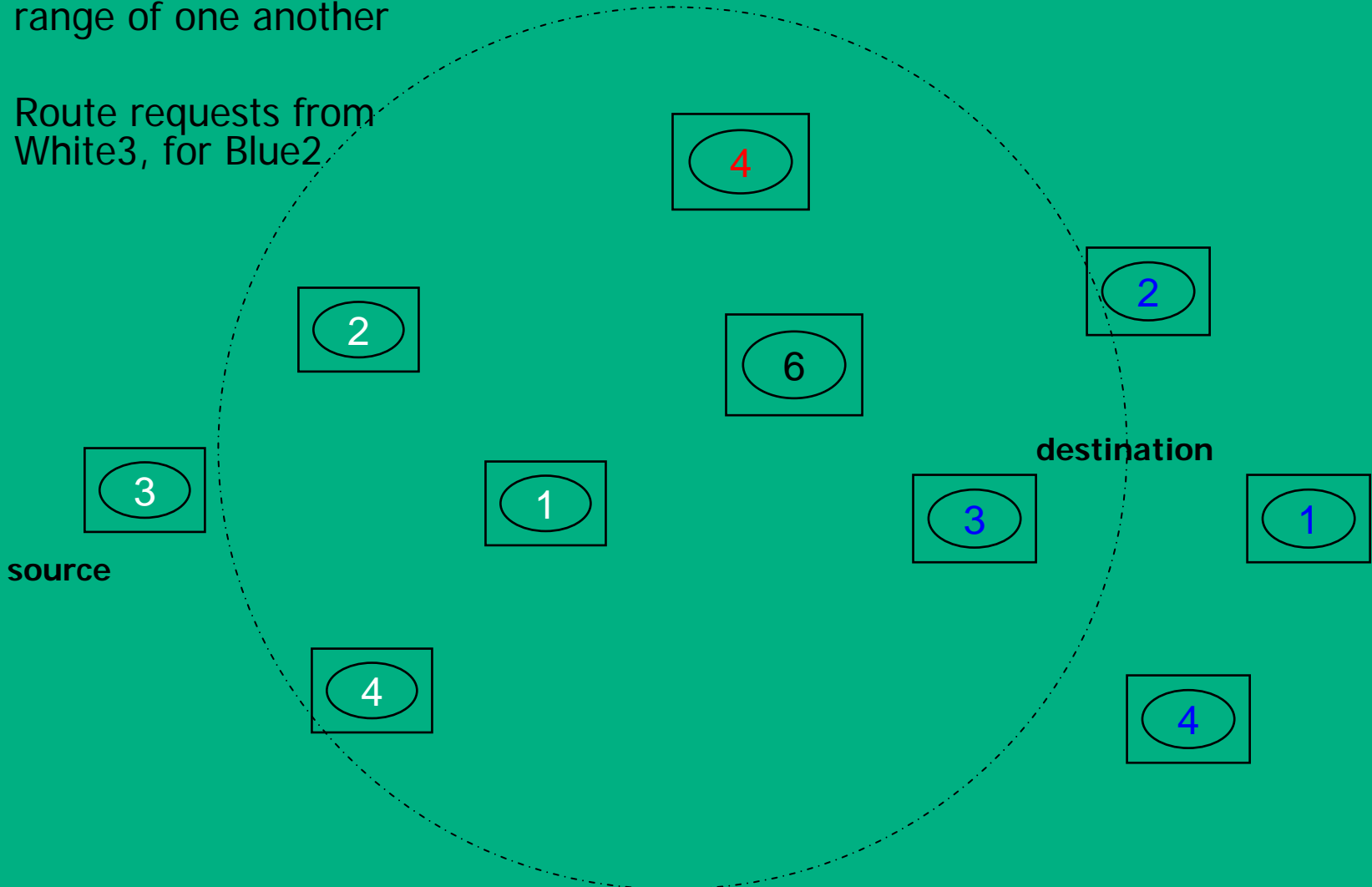
source



- All response are unicast
- Responses are based on categories
- Actual destination responds first
- Wingman responds next
- Followed by Platoon Commander
- Last to respond are all others with a route

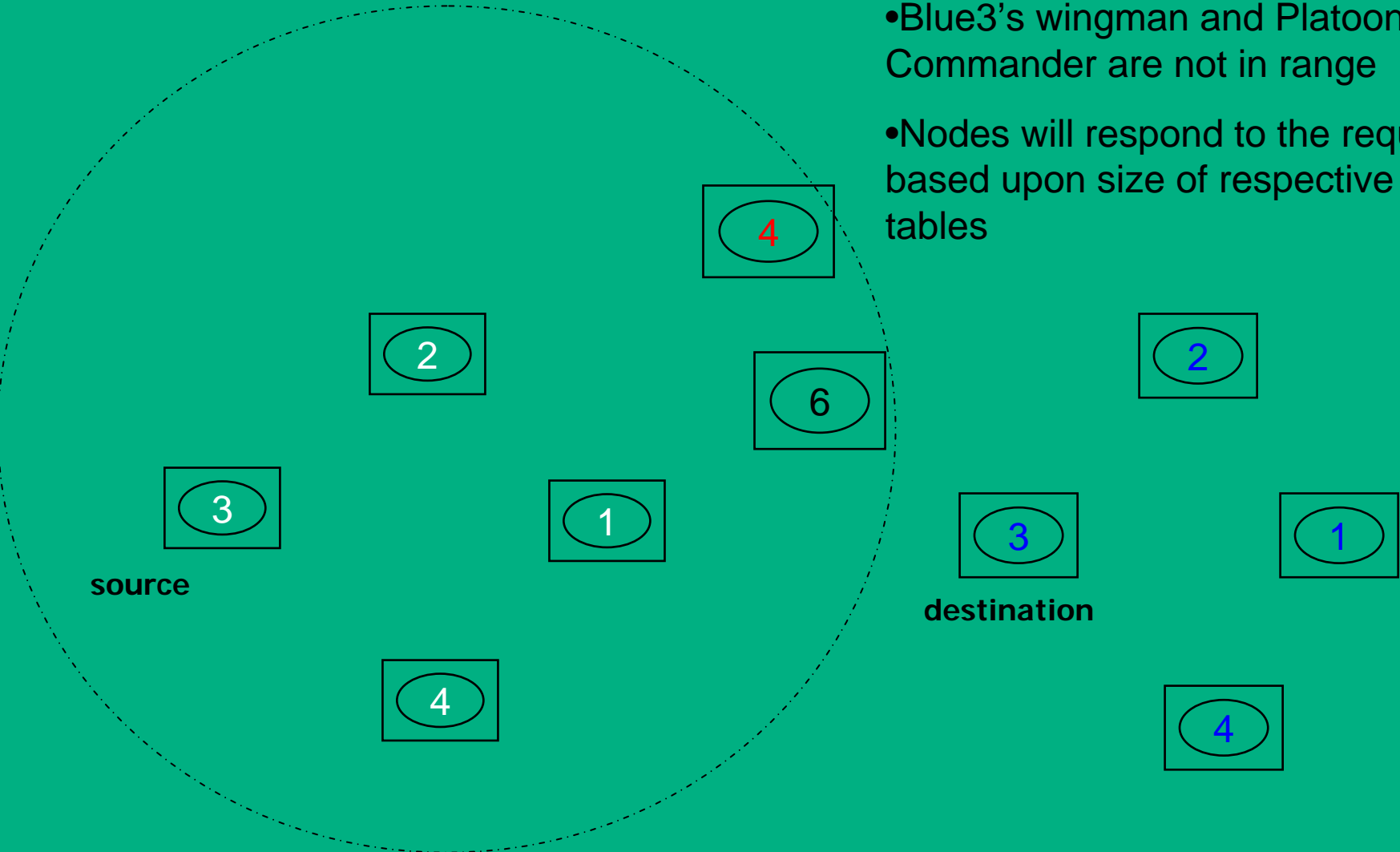
Congestion Avoidance

- Assume all within circle are within range of one another
- Route requests from White3, for Blue2



Congestion Avoidance

- Range of White3 is shown
- Blue3's wingman and Platoon Commander are not in range
- Nodes will respond to the request based upon size of respective routing tables





SINGARS Data Demo

- Tactical Chat Application
- File Transfer Capability
- Runs Directly Above Link Layer

SINGGARS Data Demo

SINGGARS Data Demo

File Edit Labels Mode

Red1: request fire support...
Red2: request confirmed. tasked to AOC...

Port Name: COM3 Baud Rate: 9600
Flow Control In: None Flow Control Out: None
Data Bits: 8 Stop Bits: 1
Parity: None Select Protocol: Aloha
My Call Sign: Red1 Send To: Red2

Open Port Close Port Send

Call signs reflect node relationships, e.g., Red1 and Red2 are wingmen to each other.



Conclusions

- Demonstrated feasibility to deploy data centric C2 capabilities with legacy voice centric radios using *only* software
- Many opportunities exist to develop low cost *stop-gap* C2/network centric capabilities for front line troops