Peer-to-peer meets wireless: Opportunities and challenges

Antony Rowstron

Microsoft Research, Cambridge

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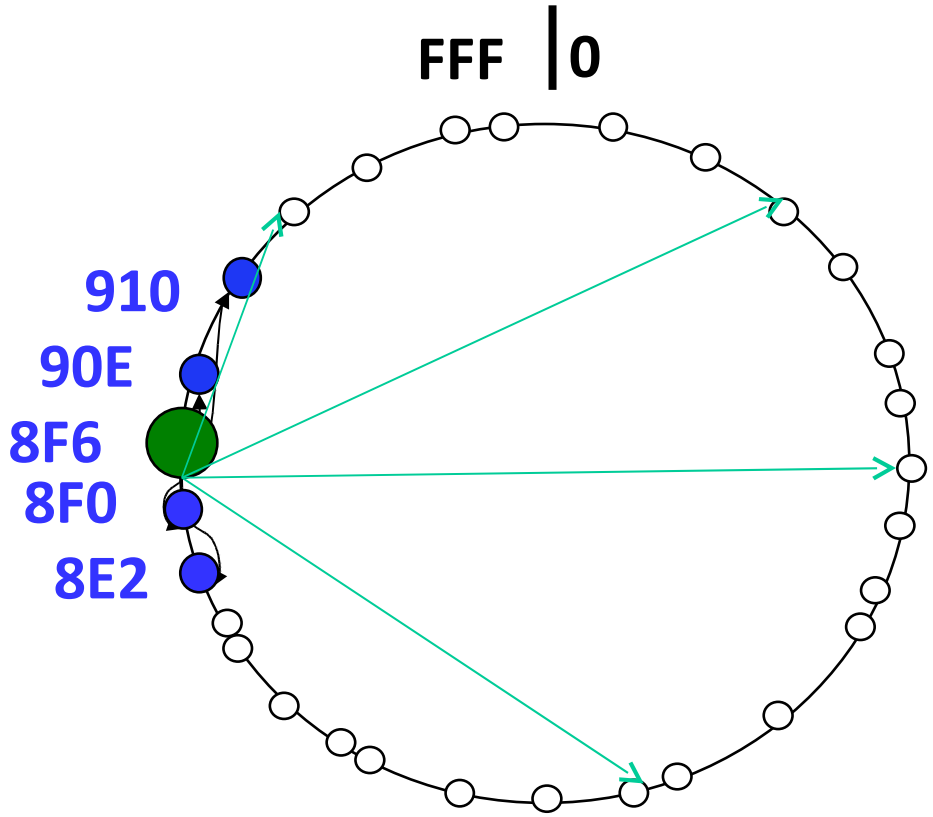
Talk outline

- Introduction (Overlays, underlays and wireless)
- Wireless routing inspired by structured overlays
  - Mesh networks
    - Design of Virtual Ring Routing (VRR)
    - Evaluation of VRR
  - Vehicular Networking
    - Design concepts of PVRP
    - Preliminary results

Structured overlays/DHTs

- Experiences learnt with structured overlays
  - Self-organizing
  - Fault-tolerant
  - Scalable
  - Decentralized
  - Performance



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Structured overlays/DHTs

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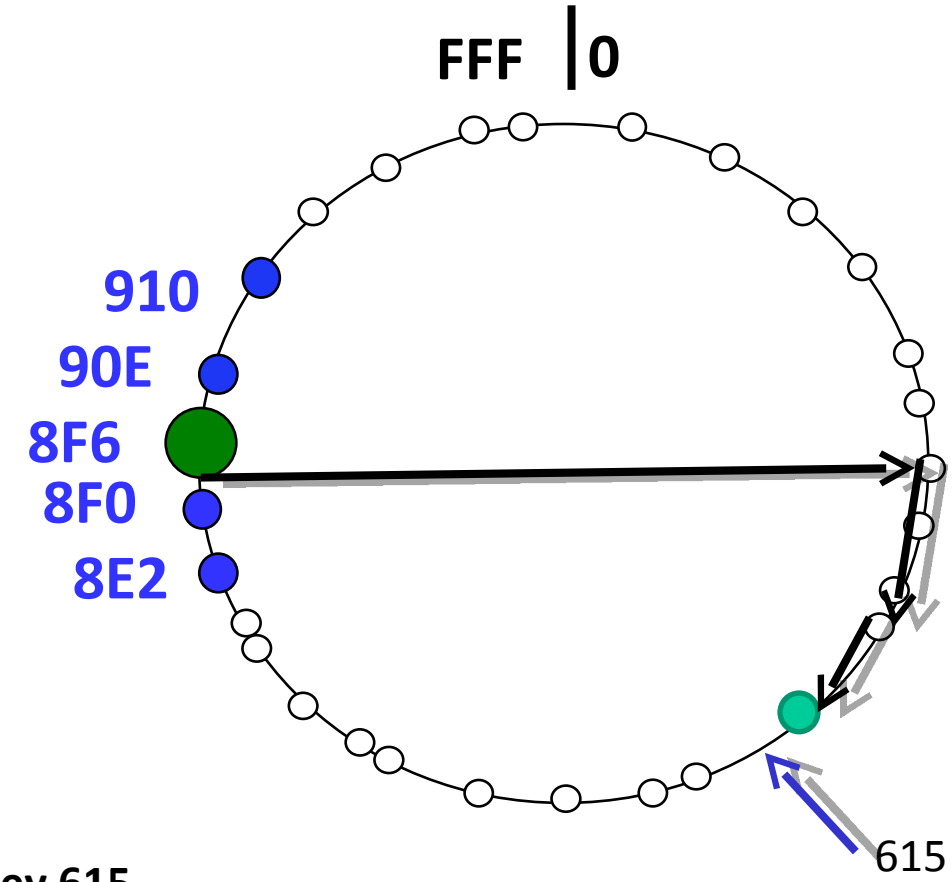

route to key 615

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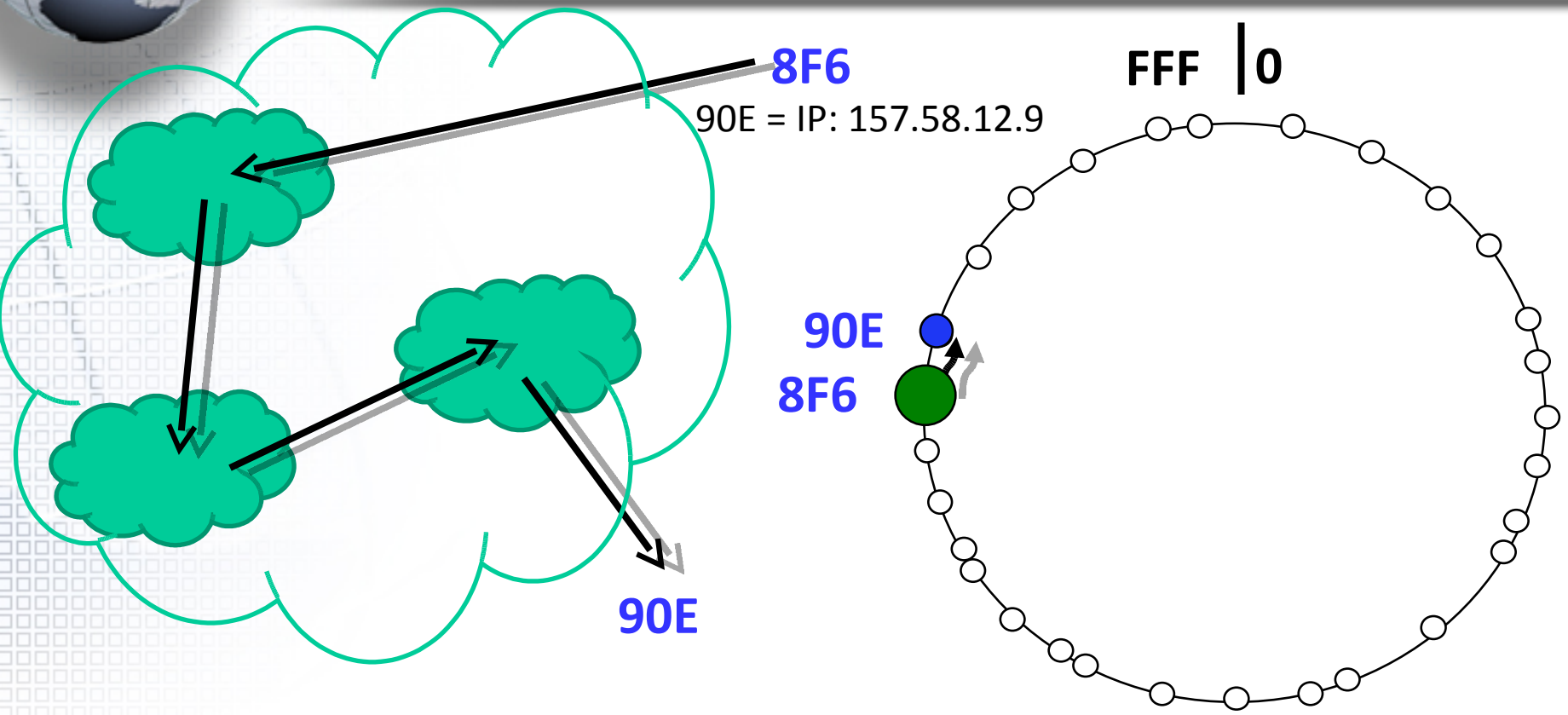
Overlay versus underlay



- Can we apply lessons to build routing protocols
  - Overlay routing at the network level

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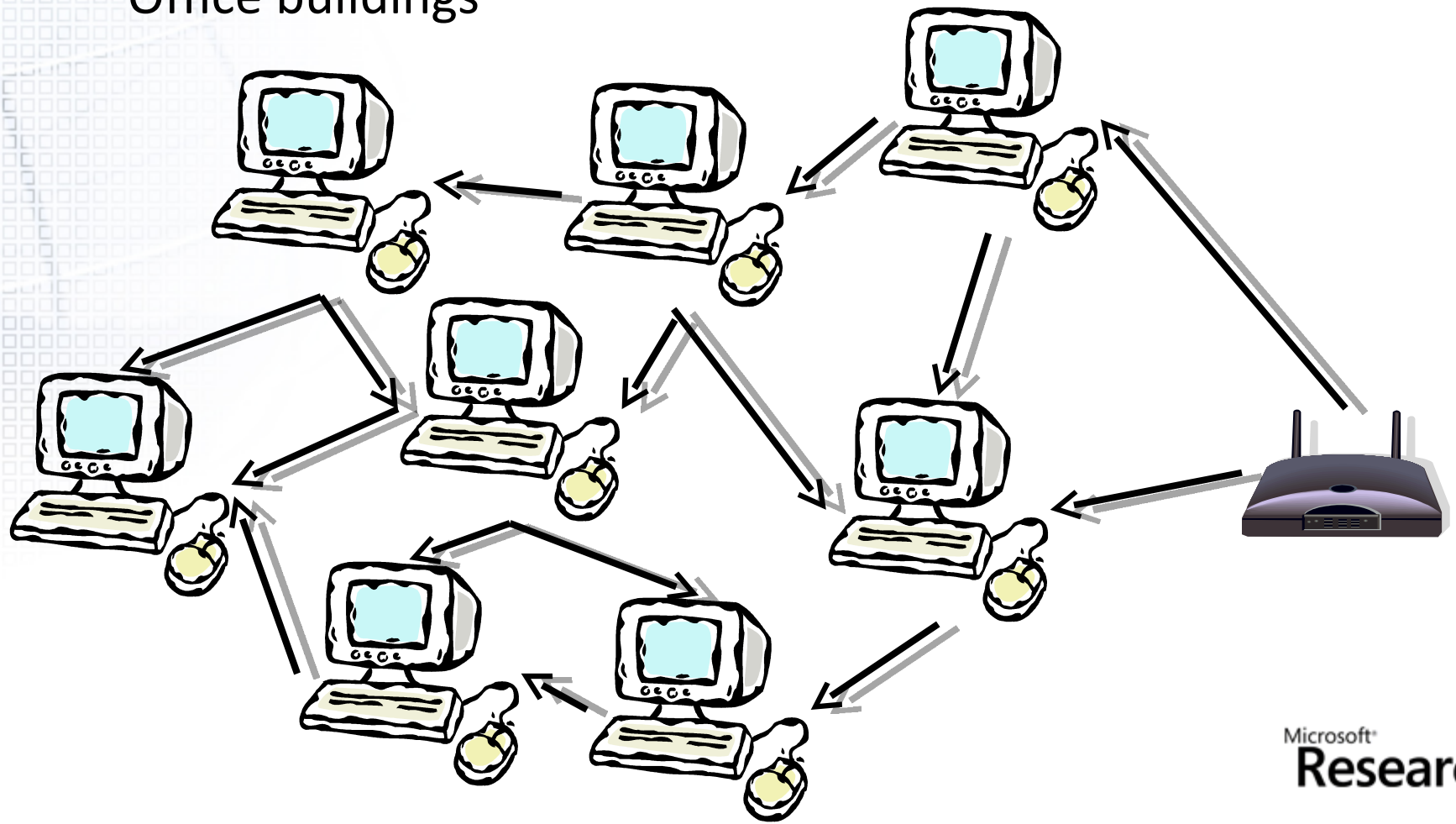
Wireless routing

- Mesh networks beginning to be deployed:
  - Office buildings



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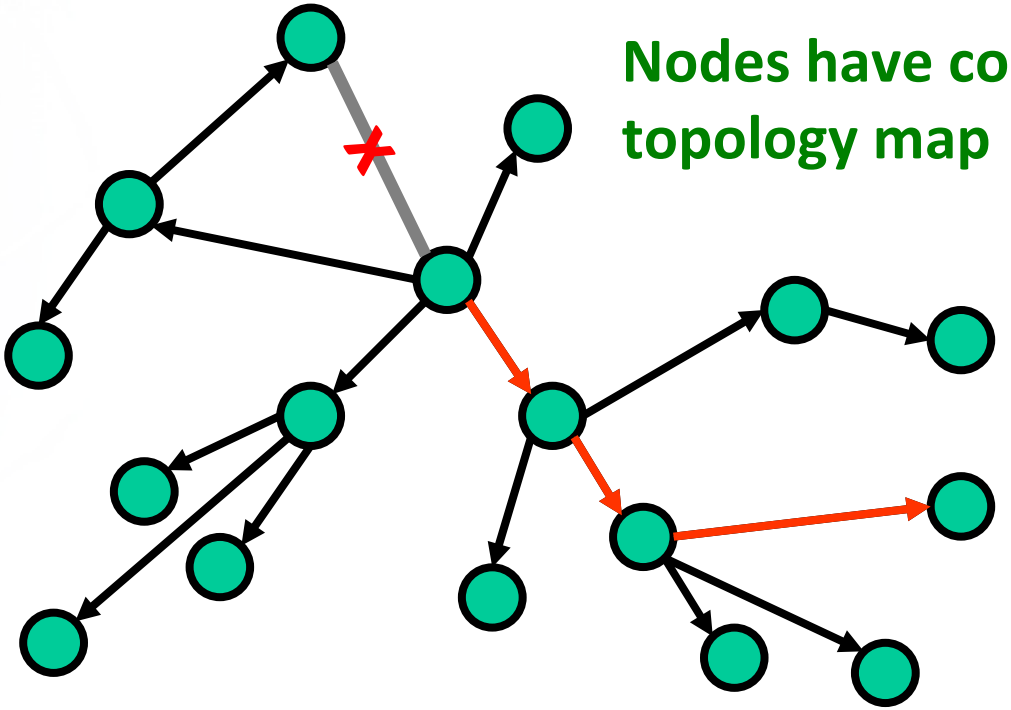
Proactive routing



Nodes have complete topology map

For example: OLSR and DSDV

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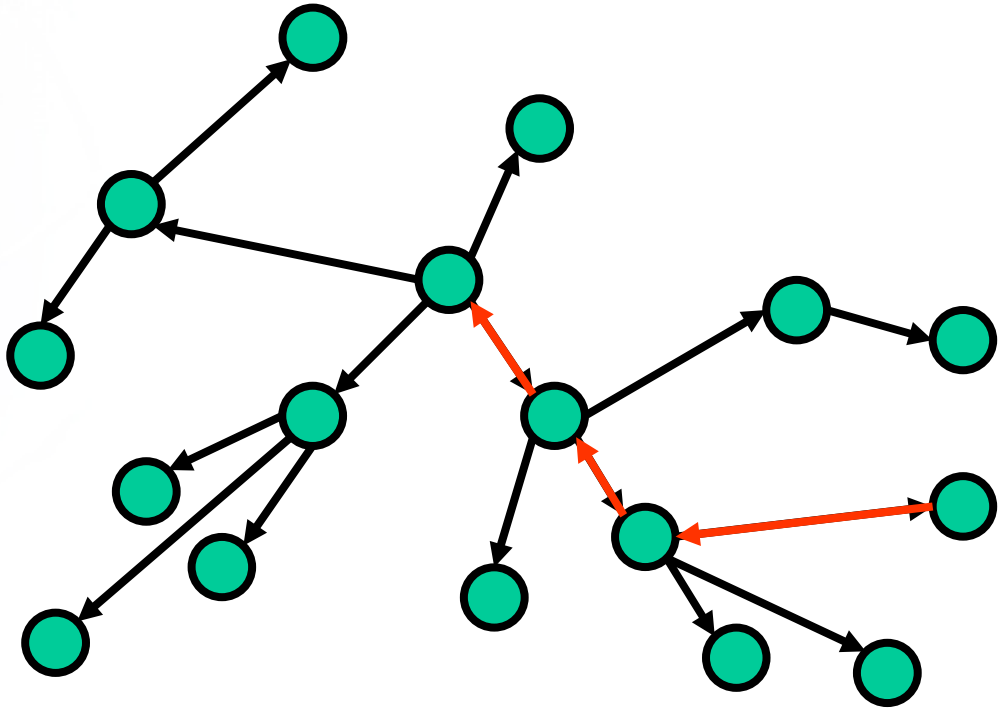
Reactive routing



For example: DSR and AODV

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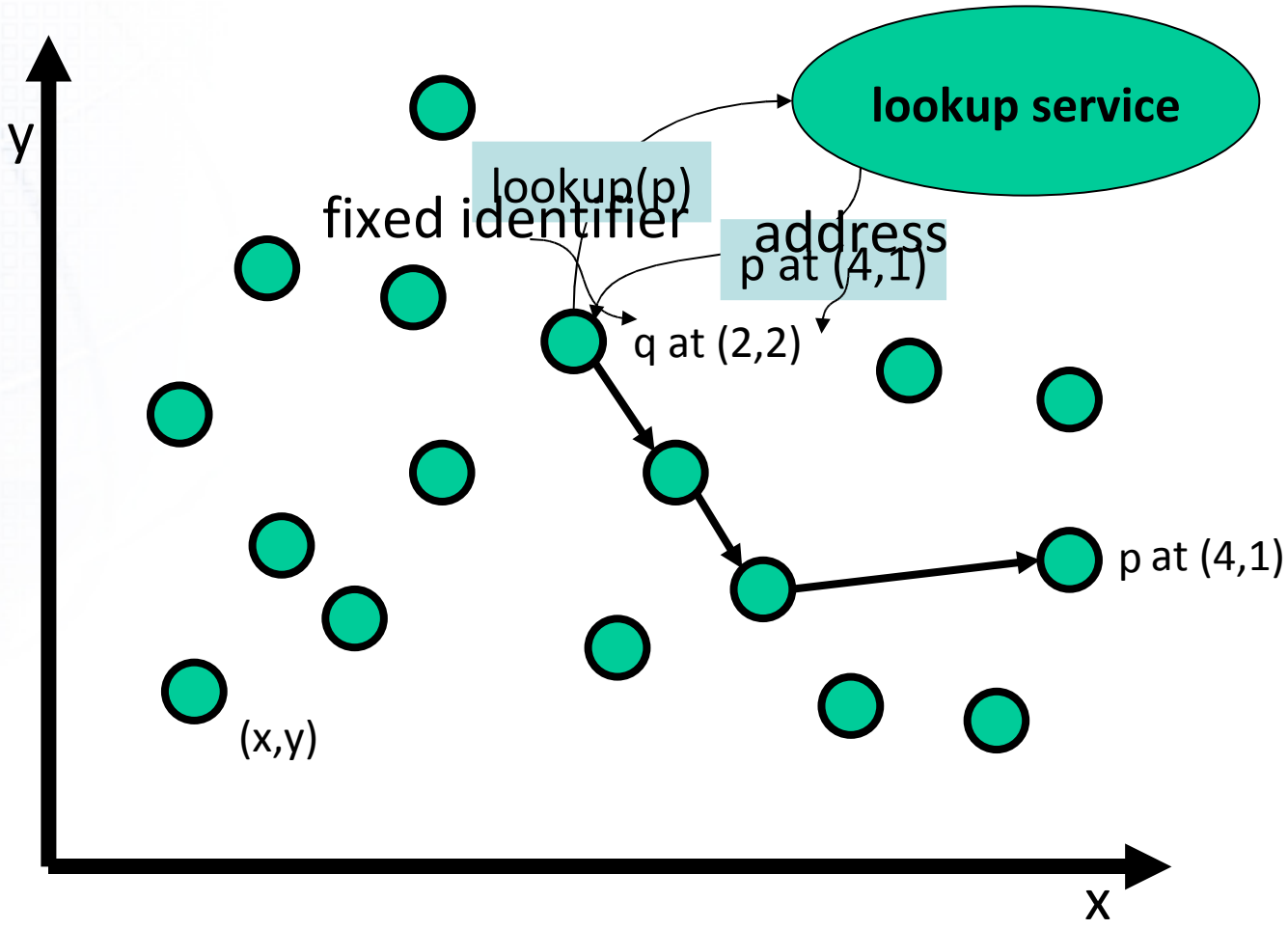
Coordinate-based routing



For example: GPSR and BVR

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Prior work on wireless routing

- Flooding based algorithms scale poorly
  - Proactive algorithms flood on topology changes
  - On demand algorithms flood to discover routes
- Geographical and landmark routing
  - Scale well but nodes have identifier and address
    - Some apps (sensor networks) may require just address
  - DHT-like structure to translate between the two
    - Route setup delays
    - Additional maintenance overhead
    - Another target for attacks

Virtual Ring Routing

Joint work with Miguel Castro, Greg O'Shea plus interns

- Virtual Ring Routing – protocol inspired by DHT design
  - Single fixed identifier
  - No flooding
  - Provides DHT for free
    - Strict layering on wireless routing is inefficient
    - Poor interaction between DHT and routing layer

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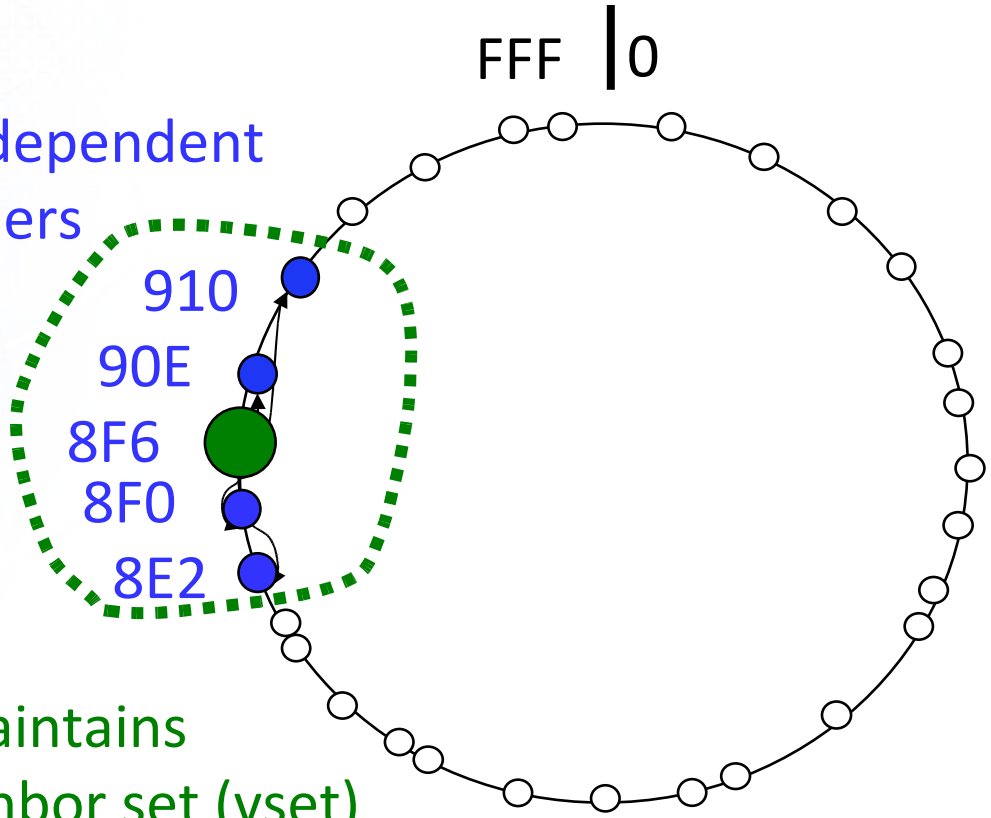
VRR: The virtual ring



Topology-independent
node identifiers

Each node maintains
a virtual neighbor set (vset)

Nodes organized into virtual ring
by increasing identifier value

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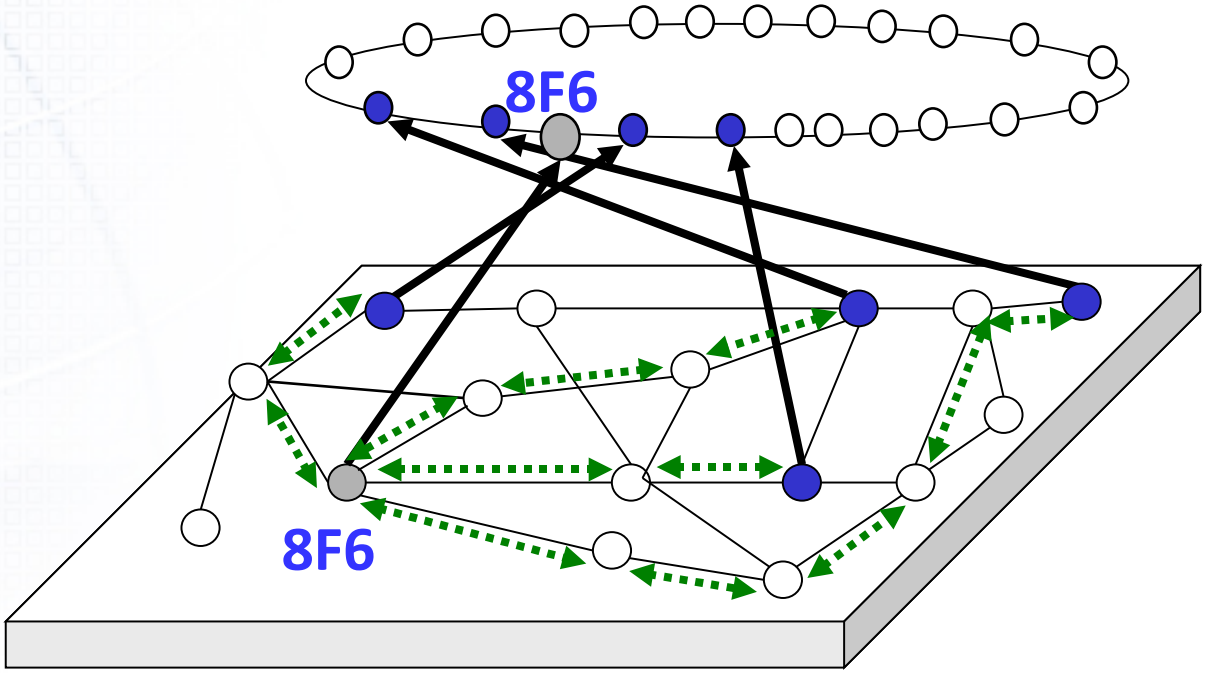
VRR: Routing paths



physical network topology

Nodes only maintain routing paths to virtual neighbors:

- Paths maintained proactively
- Paths are bidirectional and typically multi-hop

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VRR: Forwarding table

endpointA	endpointB	nextA	nextB	pathId
8F6	90E	me	F42	31
910	8F6	10E	me	10
14A	140	F42	10E	2
8F6	F42	me	F42	FF

forwarding table for node 8F6

- Paths recorded in forwarding tables along path
- Forwarding table contains
  - Paths between node and vset members
  - Paths between other nodes that go through node
  - Paths to physical neighbors

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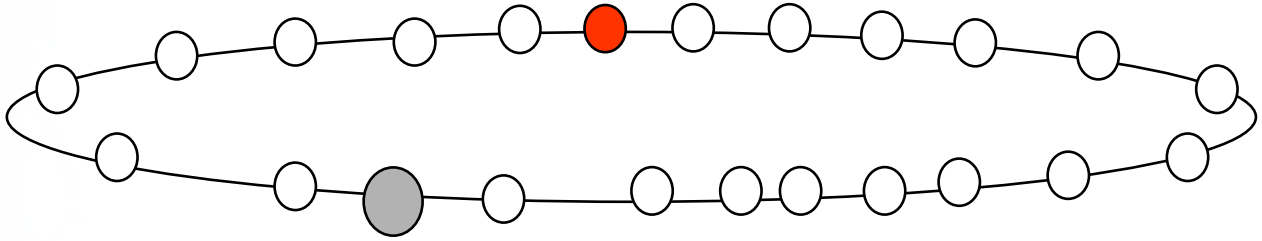
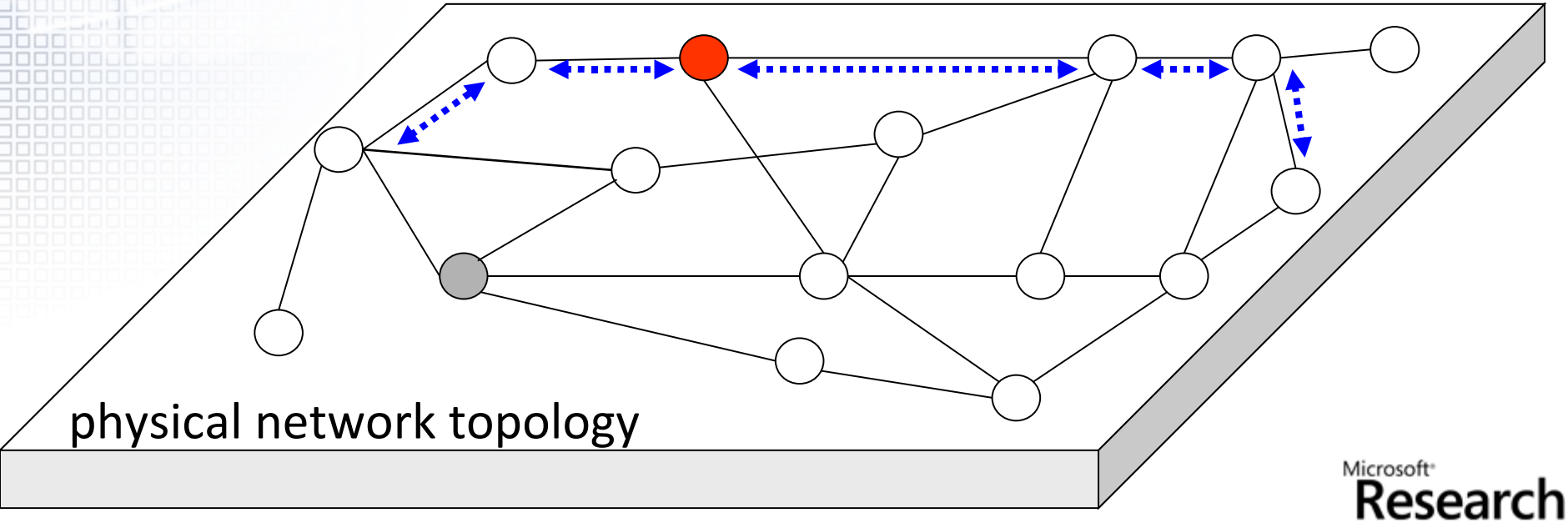
VRR: Routing

- Forward message destined to *x* by
  - Picking endpoint *e* numerically closest to *x*
  - Forwarding message to next hop towards *e*
- Deliver message to node with id closest to *x*

VRR: Example routing





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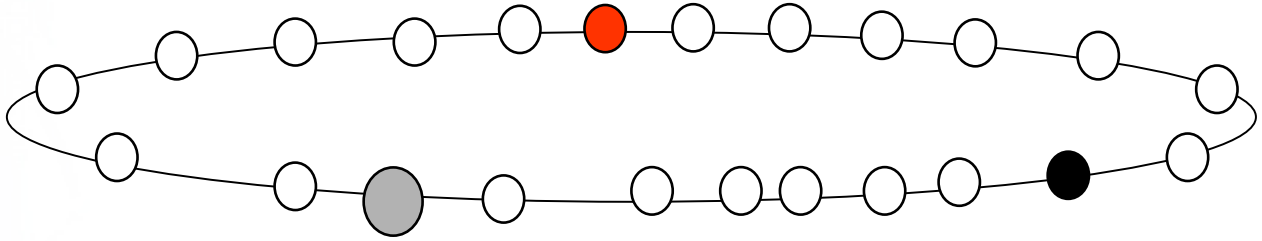
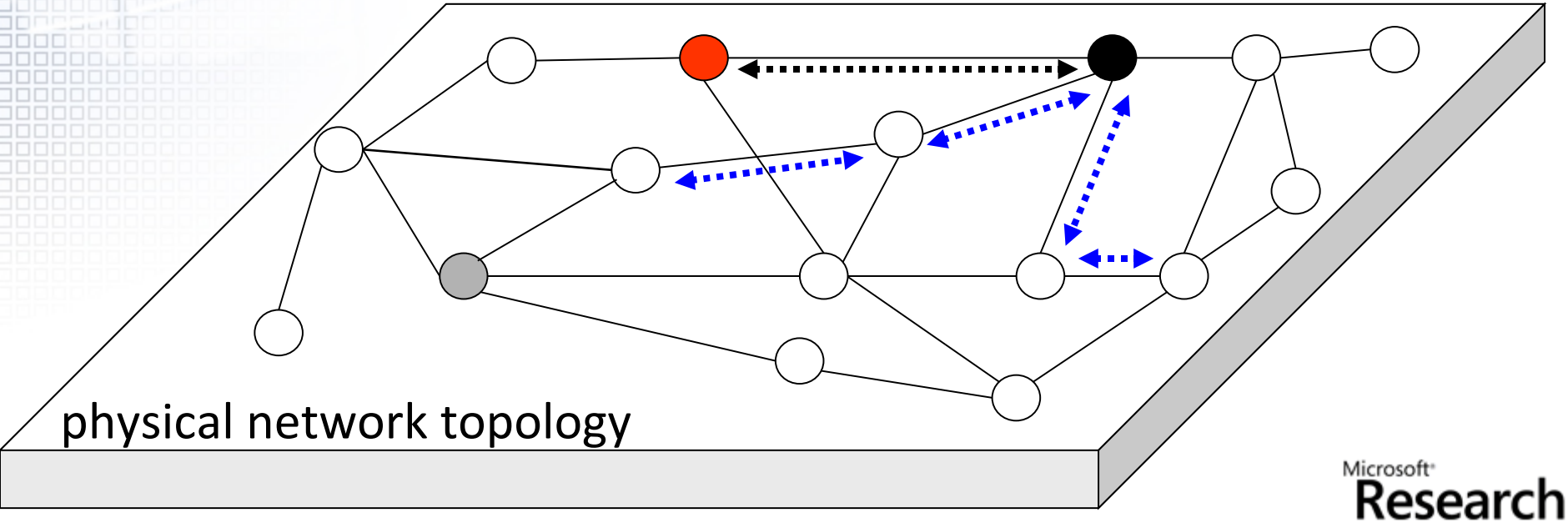
VRR: Example routing





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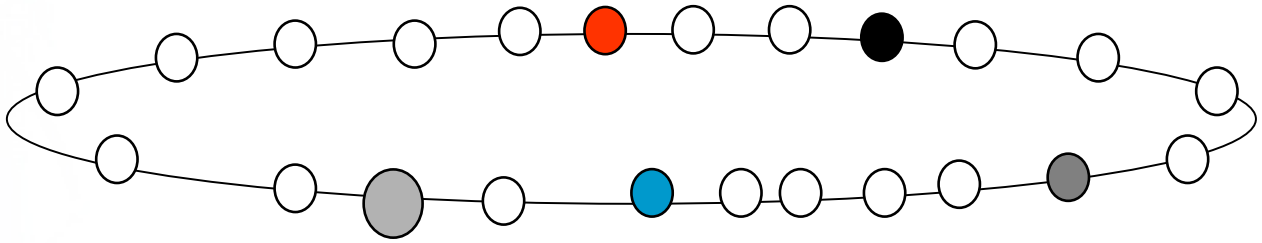
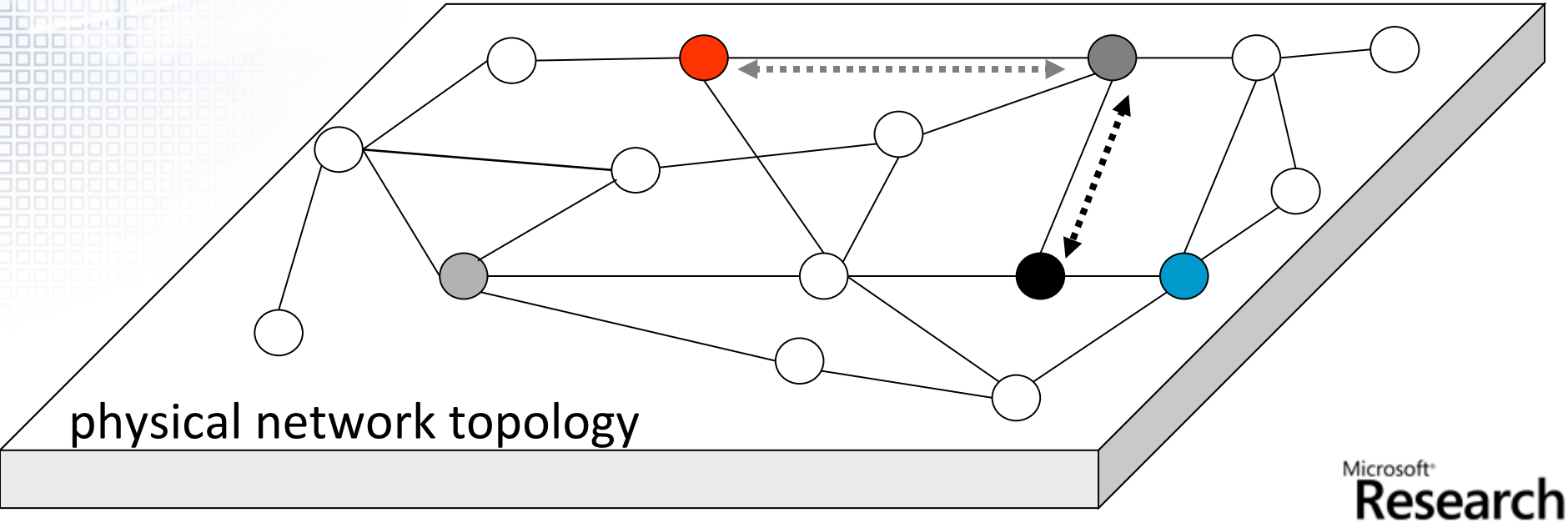
VRR: Example routing





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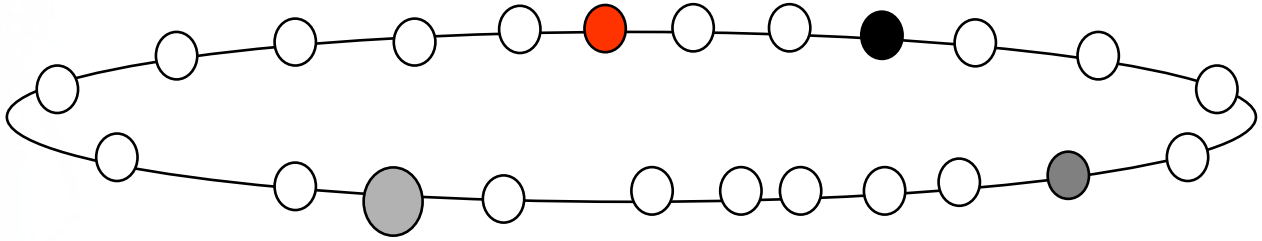
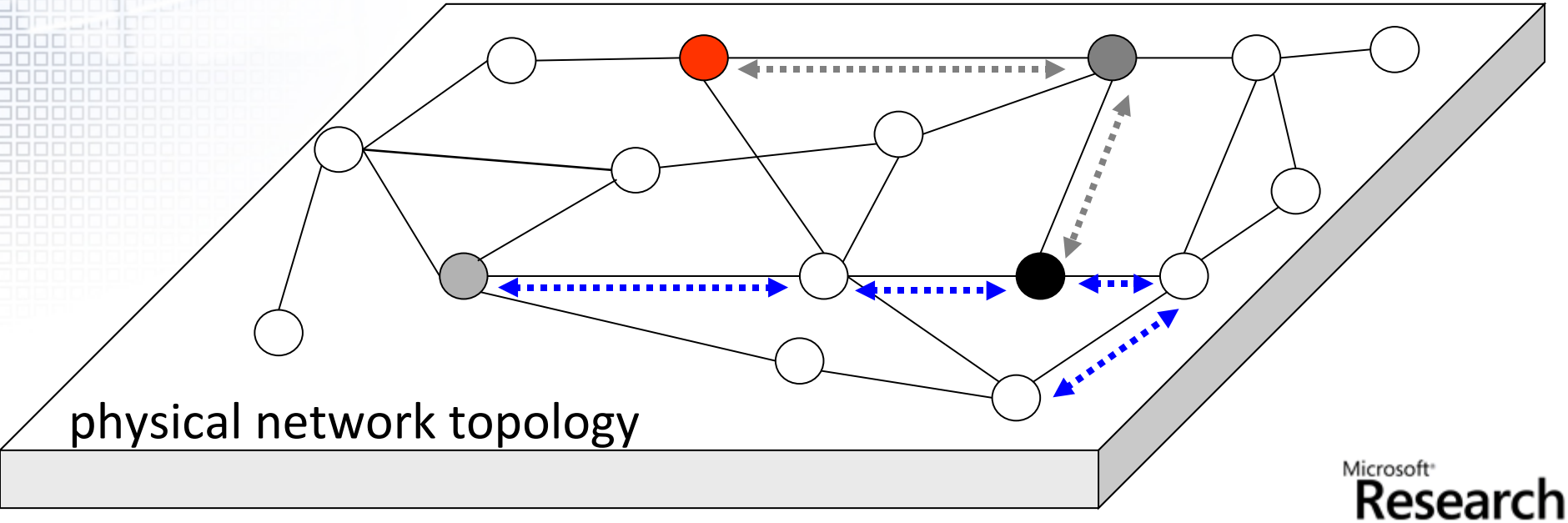
VRR: Example routing





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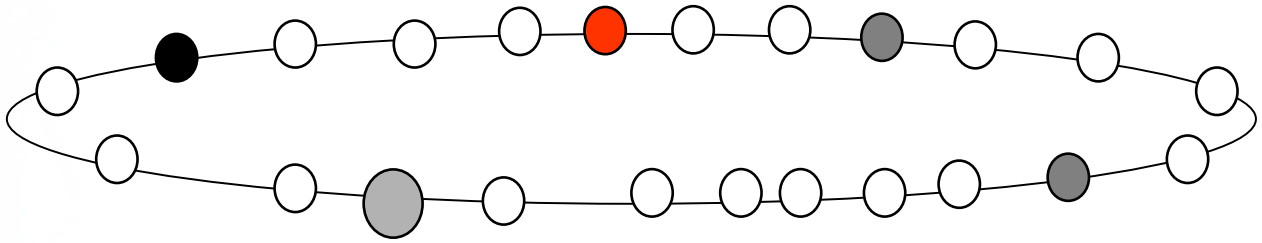
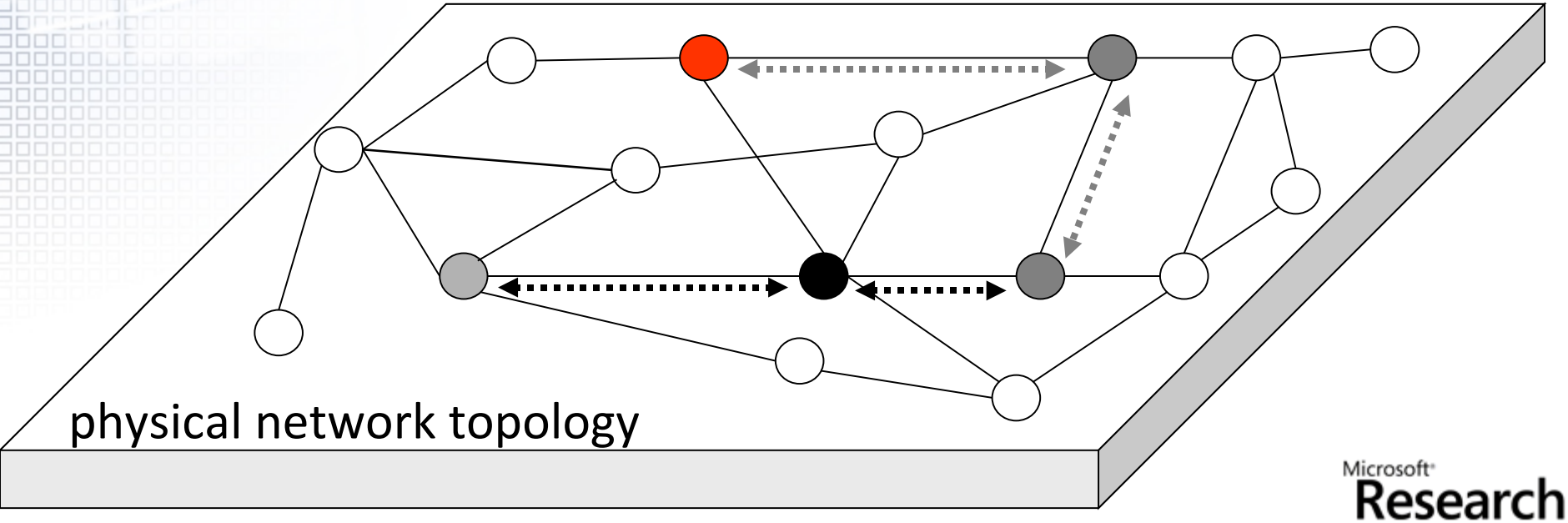
VRR: Example routing





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VRR: Routing summary

- Paths to virtual neighbors ensure correctness
- Stretch empirically small
- Many alternate paths to route around failures

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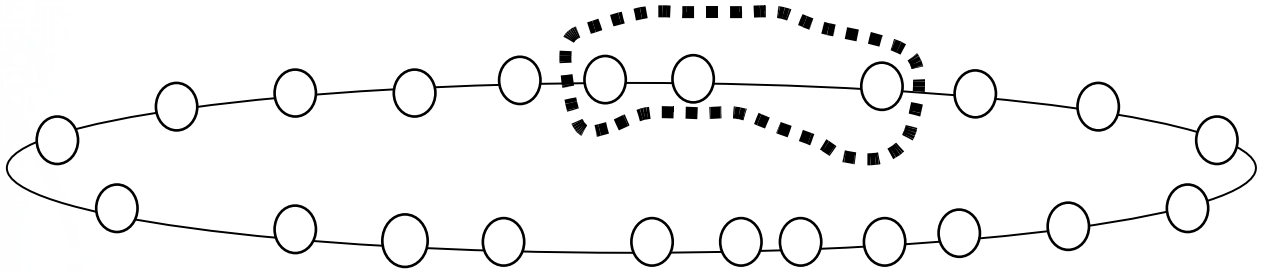
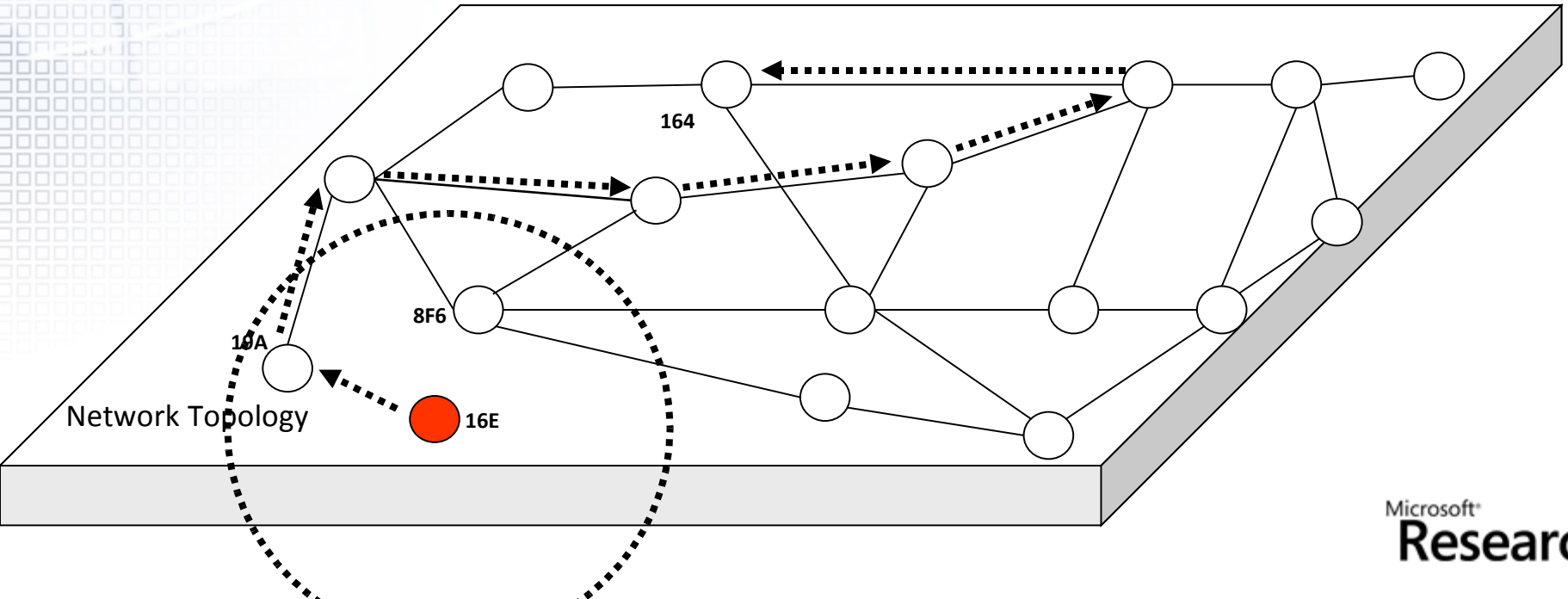
VRR: Ring maintenance

- No flooding
  - All messages routed as described
- Single topology independent identifier
- Five message types
  - hellos maintain physical neighbor set
  - setups update forwarding table state along path
  - setup requests ask another node to send setup
  - setup replies refusal to send setup
  - teardowns remove forwarding table state

VRR: Node joining



broadcast hellos
Send setup request to 16E
to find physical neighbors



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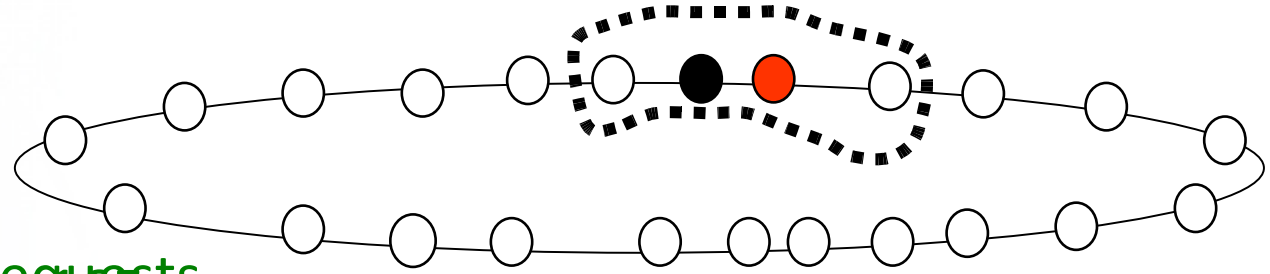
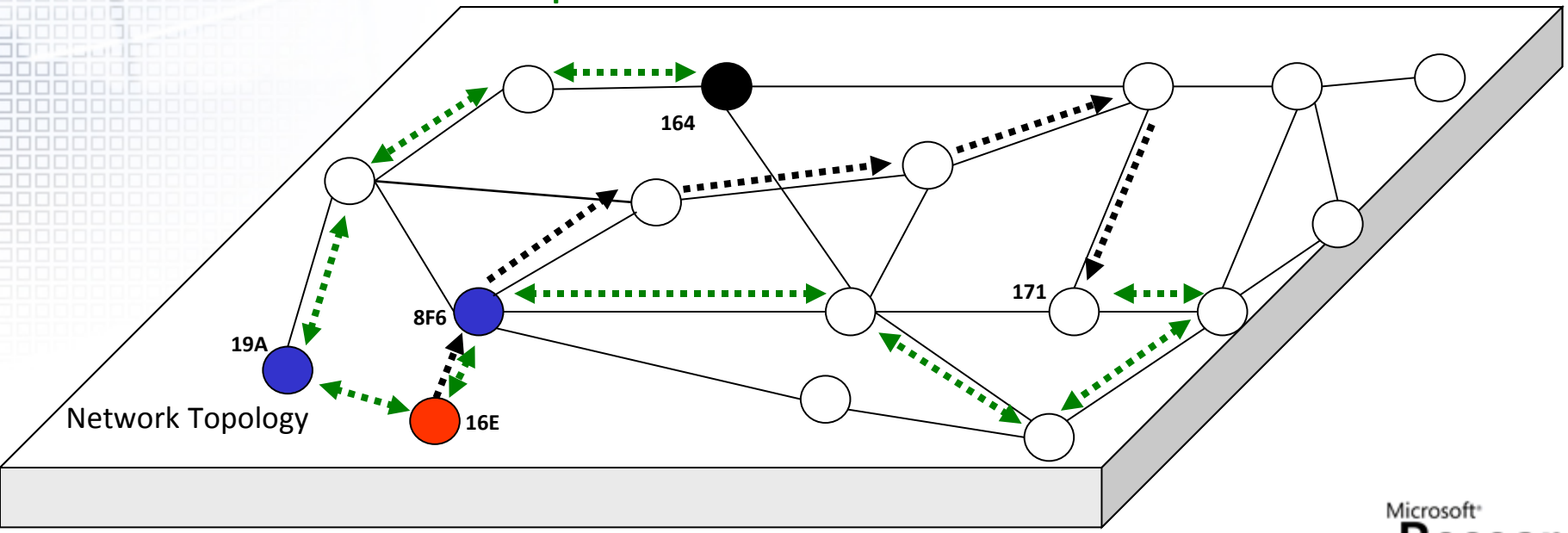
VRR: Node joining



16E sends setup requests
16E adds node to vset
to nodes in received vset
when it receives setup



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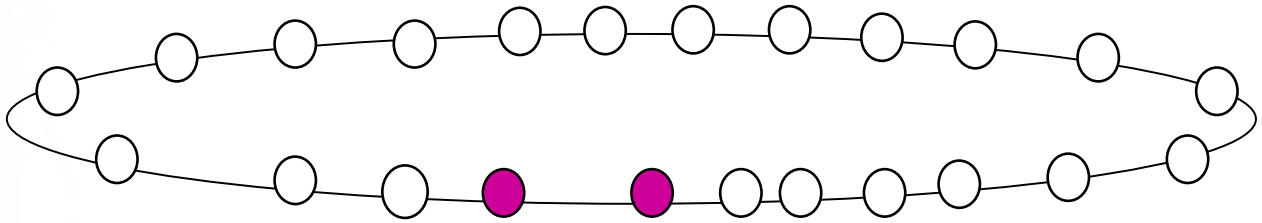
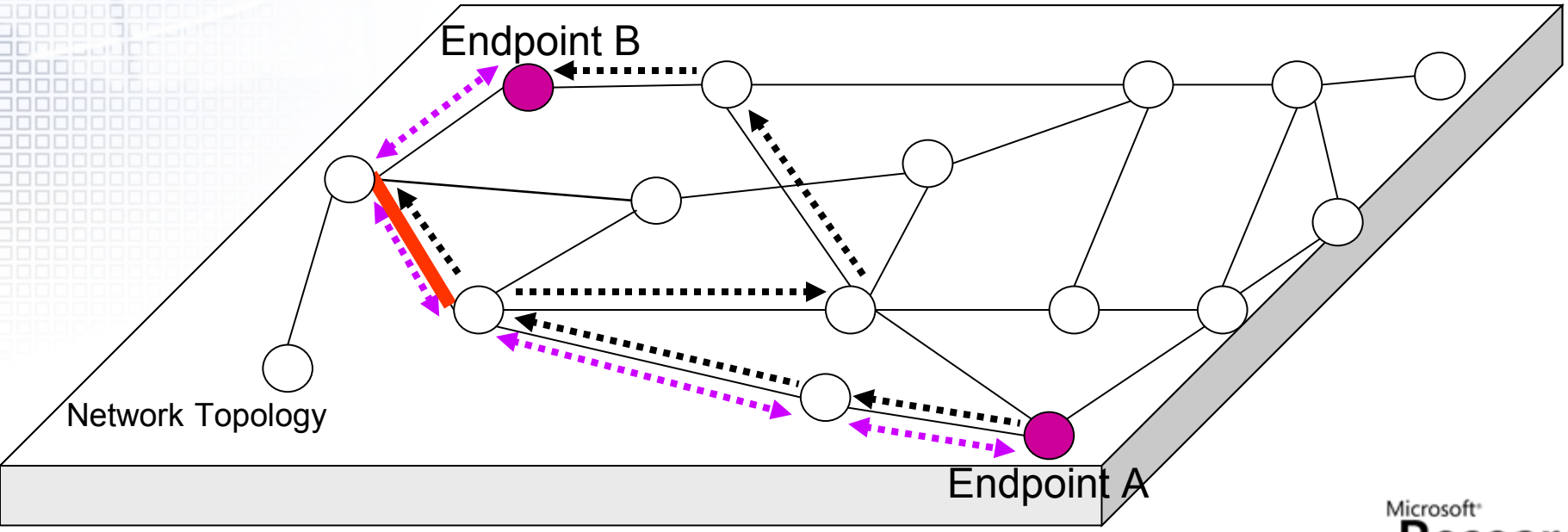
VRR: Handling failures

- **Routing state is hard**
  - No end-to-end heartbeats
  - Failures detected on missing acks or hellos
  - Local repair attempted first;
  - Otherwise, teardowns sent along all affected paths
- Two techniques to ensure consistency
  - Symmetric failure detection and acks on teardowns
    - If *x* marks *y* faulty, *y* is guaranteed to mark *x* faulty
  - Lightweight optimistic transactions
    - If in doubt abort (teardown)

Routing during node or link failure





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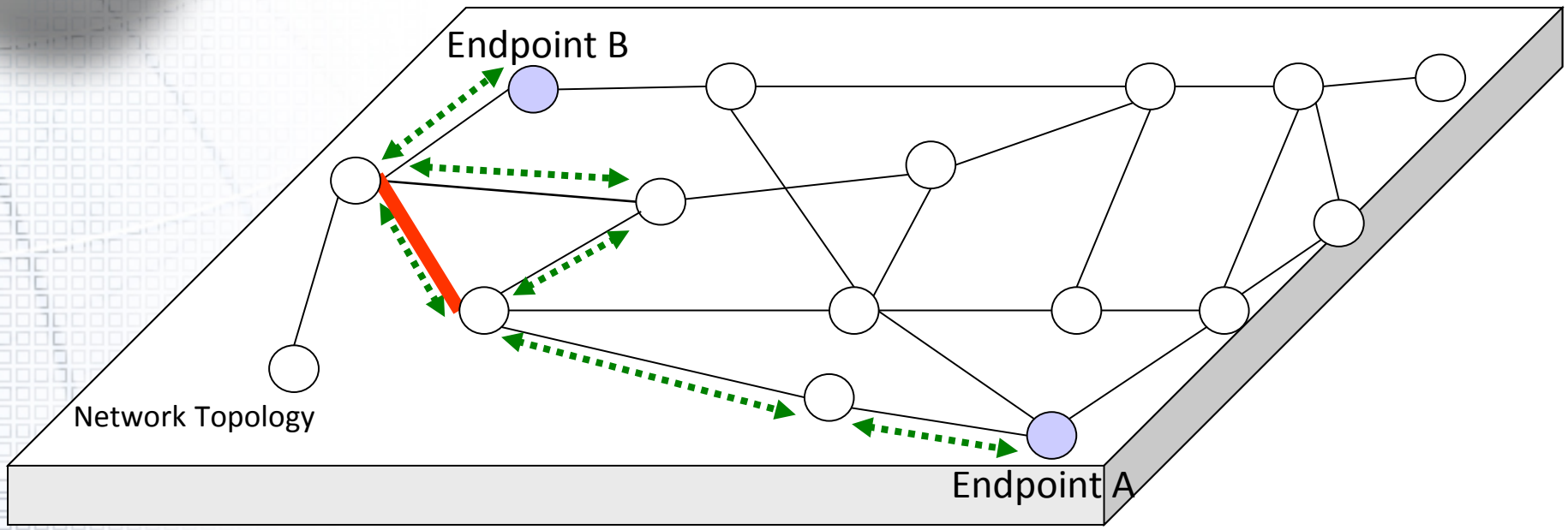
A link failure example



- **Repair is truly local**
  - Only involves nodes near failed link or node
  - No end-to-end path metrics
- Repair **aborted** if local consistency checks fail

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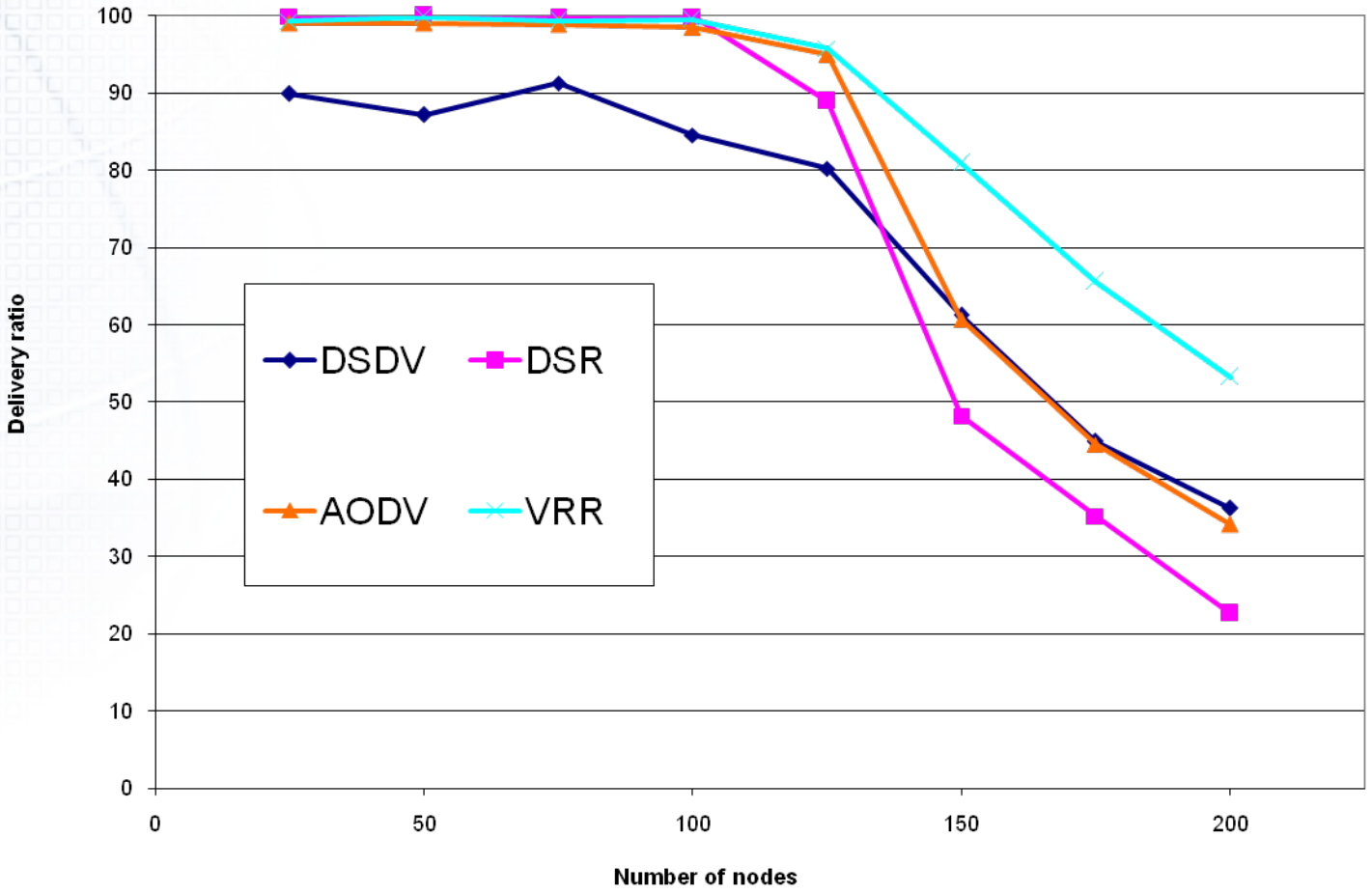
Simulation experiments in ns-2

- Experiments with 802.11b MAC
- Varied network size, mobility, session lifetime
- Compared with DSDV, DSR, and AODV

- VRR performed well in all experiments
  - high delivery ratios even with fast movement
  - significantly lower delays with route instability

Delivery ratio: fast movement



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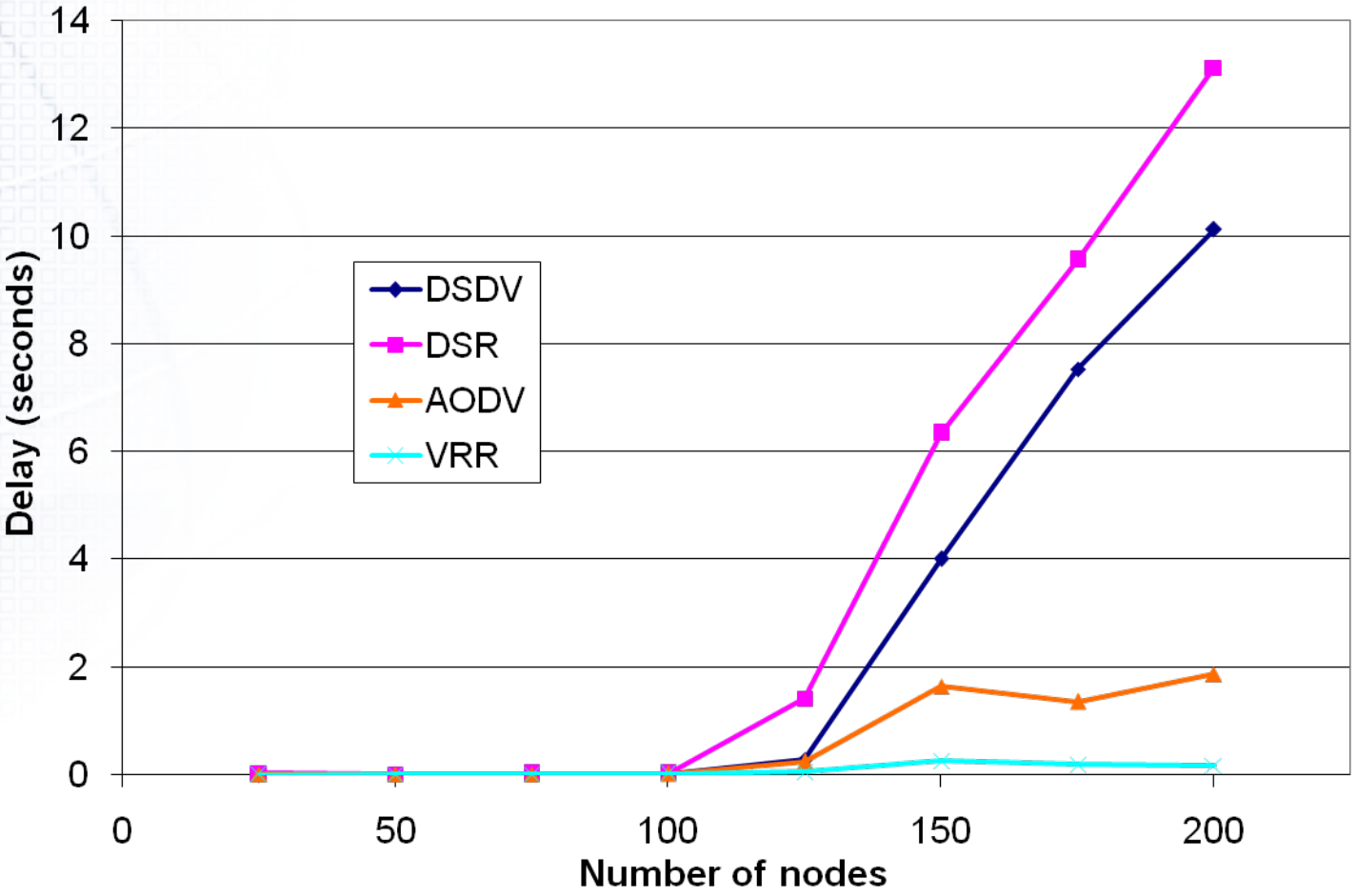
Delay: fast movement



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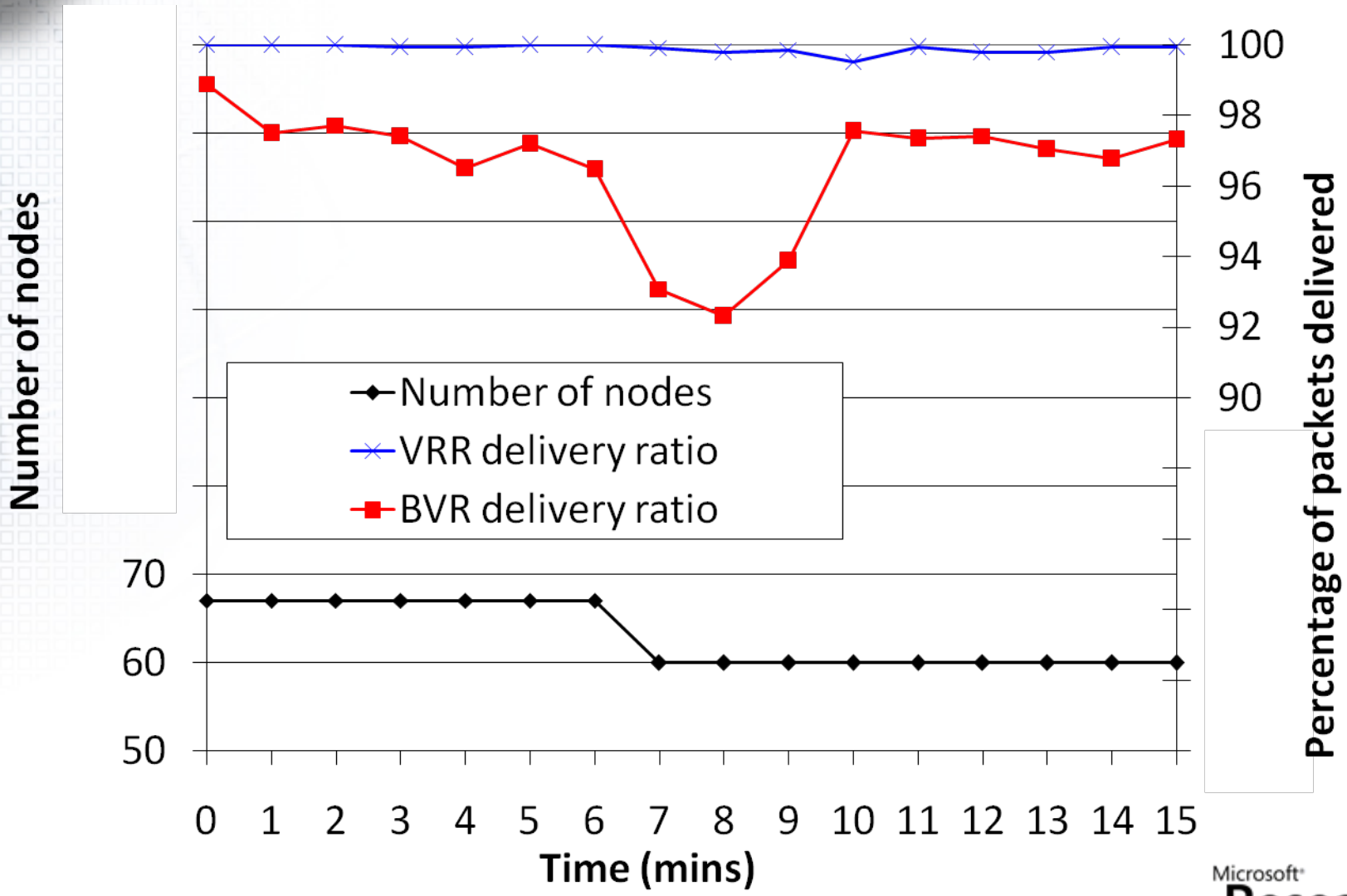
Sensor network

- Sensor network testbed
  - 67 mica2dot motes in UCB building
- Comparison with BVR (coordinate-based protocol)
- Delivery ratio with mote failures

Sensor network: mote failures



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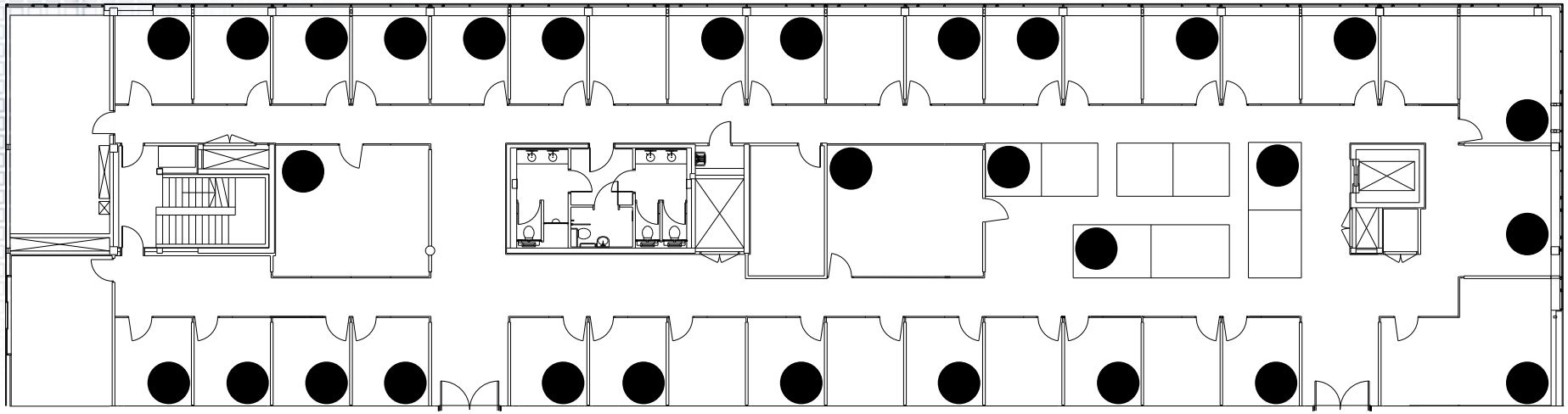
Wireless office testbed

- 30 machines running windows
- Communicate using 802.11a
- Throughput comparison with LQSR using ttcp



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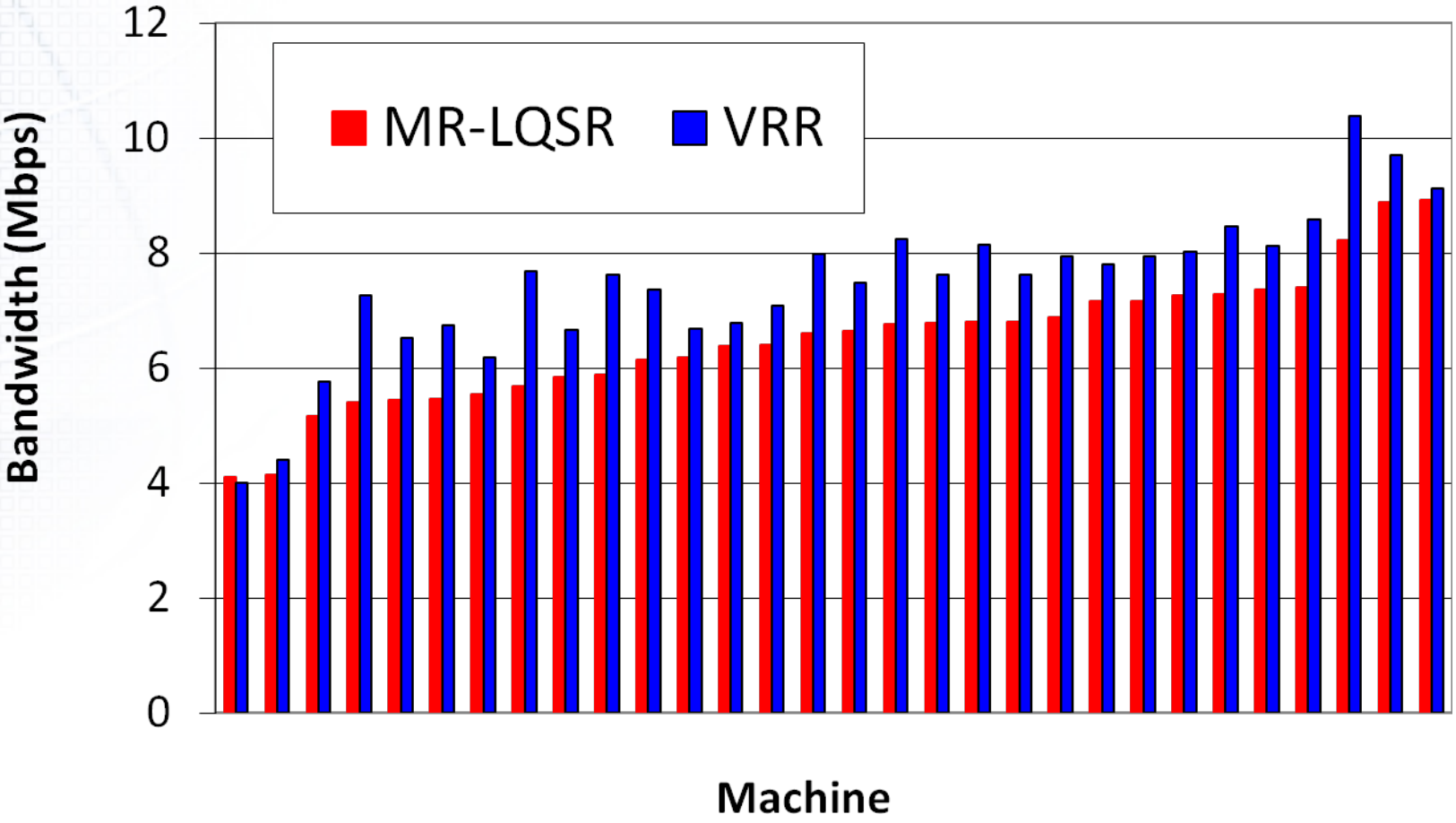
Wireless office testbed: throughput



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Virtual Ring Routing Summary

- Routing protocol inspired by structured overlays
- Unique (new point in the design space):
  - Single identifier per node
  - No flooding
- Provides DHT for free

- For more information see:
  - M. Caesar, M. Castro, E. Nightingale, G. O'Shea and A. Rowstron, **"Virtual Ring Routing: Network routing inspired by DHTs"**, Sigcomm 2006, Pisa, Italy, September 2006**.**

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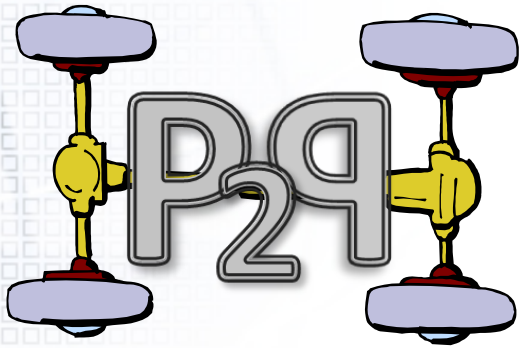
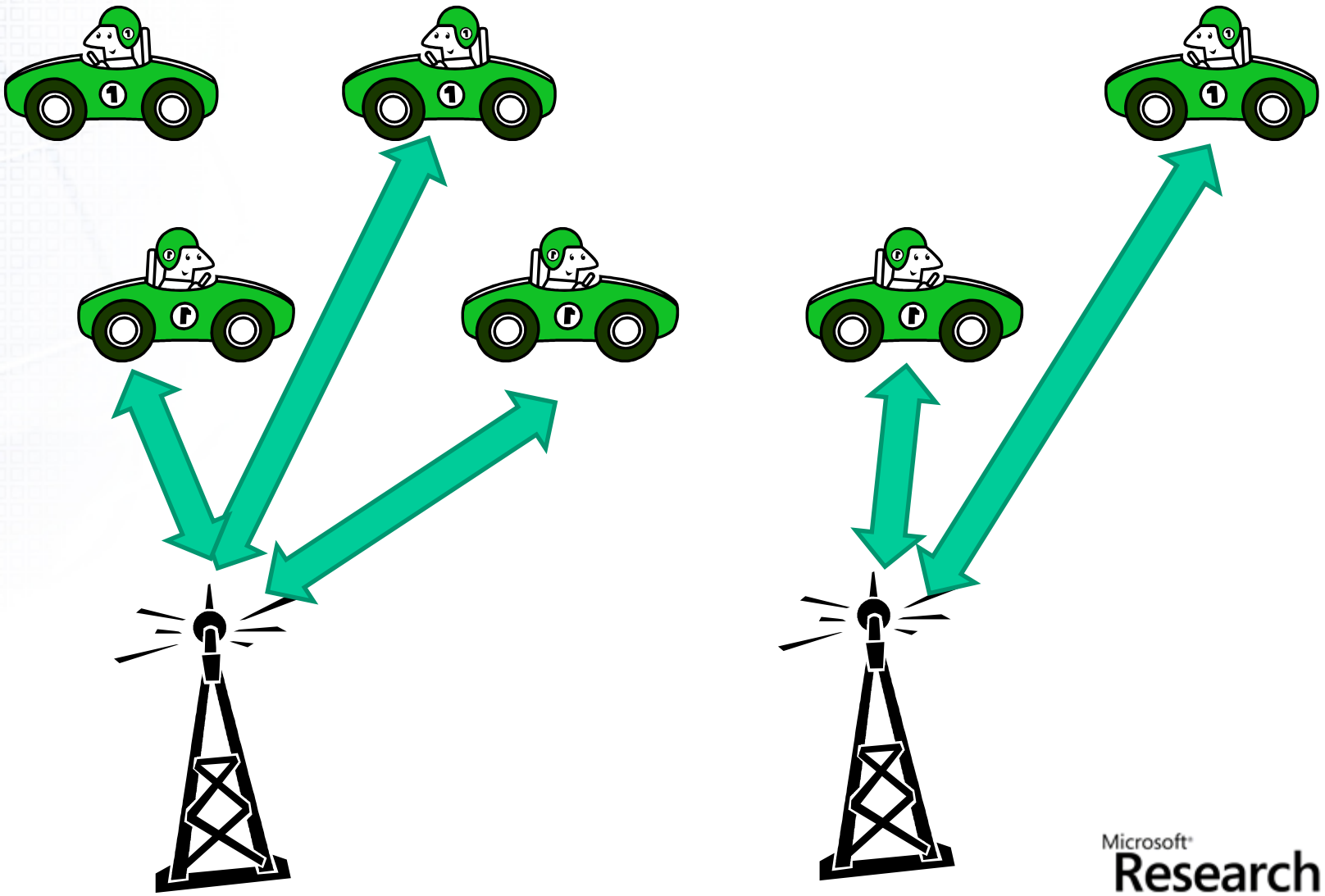
Vehicular networking

- New challenges for scalability
  - Very different characteristics



Vehicle-to-Infrastructure (V2I)



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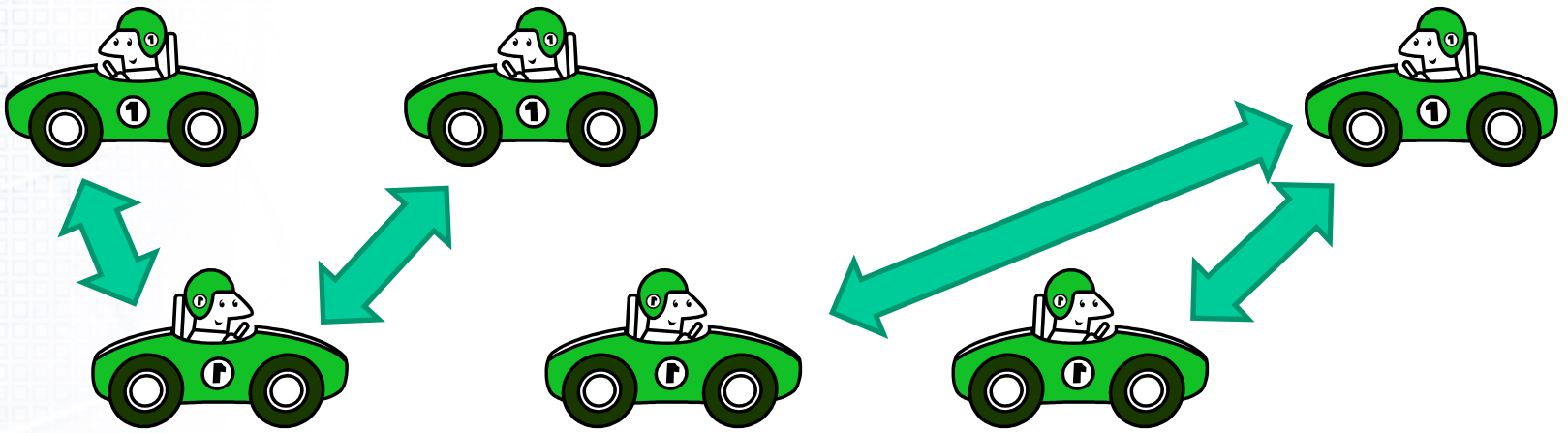
Vehicle-to-Vehicle (V2V)



- Car manufacturers interested and “driving”:
  - 802.11p (Dedicated short range communications)
  - Intelligent Transport Systems
    - “What is the car in front doing?”
- But then.....

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The disruptive device……

- SatNav (TomTom)
  - Dual connectivity model:
    - Bluetooth to mobile phone
    - USB-to-computer (new map > 1Gb)
  - Download data for premium services (Home service)
    - TomTom Map Share (Web 2.0 app)
    - TomTom QuickFix (Assisted GPS)
    - TomTom Updates
  - “Connectivity key”

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Personal Navigation Devices

"Hand held" or In-dash!

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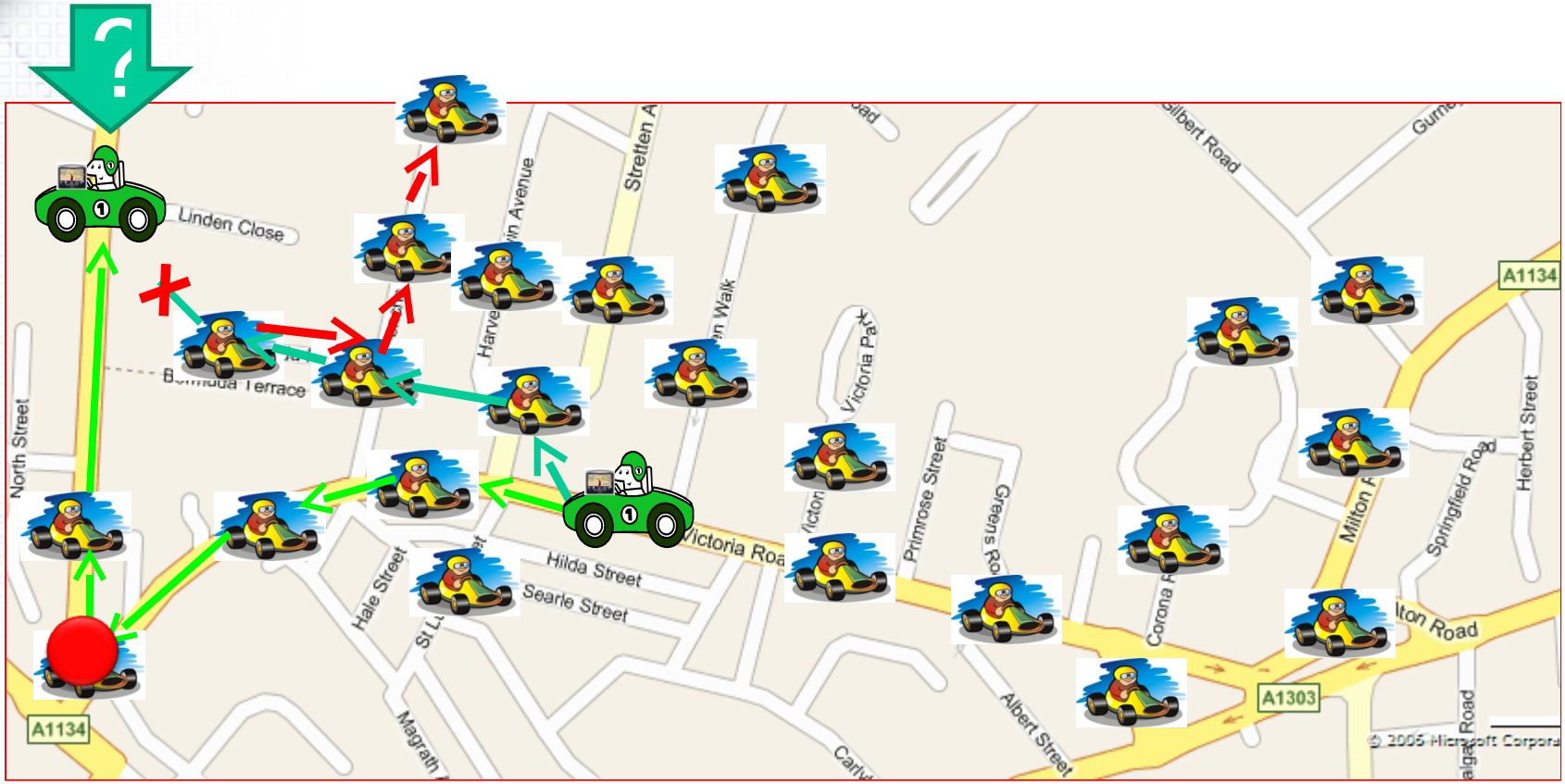
PVRP: Practical Vehicular Routing Protocol

Joint work with G. Pau and P. Lutterotti (UCLA)

- Multi-hop vehicle-to-infrastructure
  - Route to fixed access points
- Multi-hop vehicle-to-vehicle
  - Route to specific vehicle or a service

- Why do we need another routing protocol?

Greedy Routing



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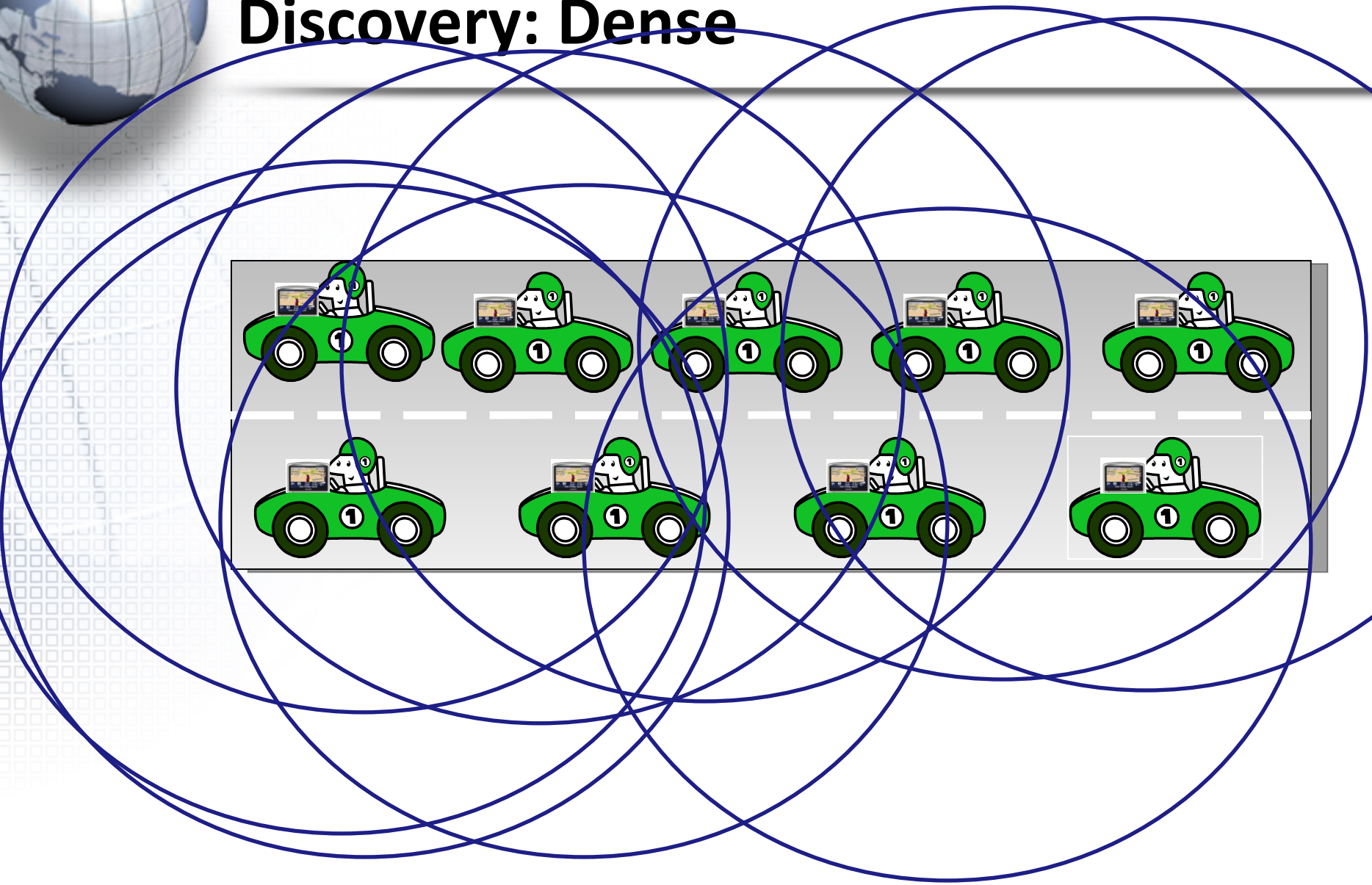
Discovery: Dense



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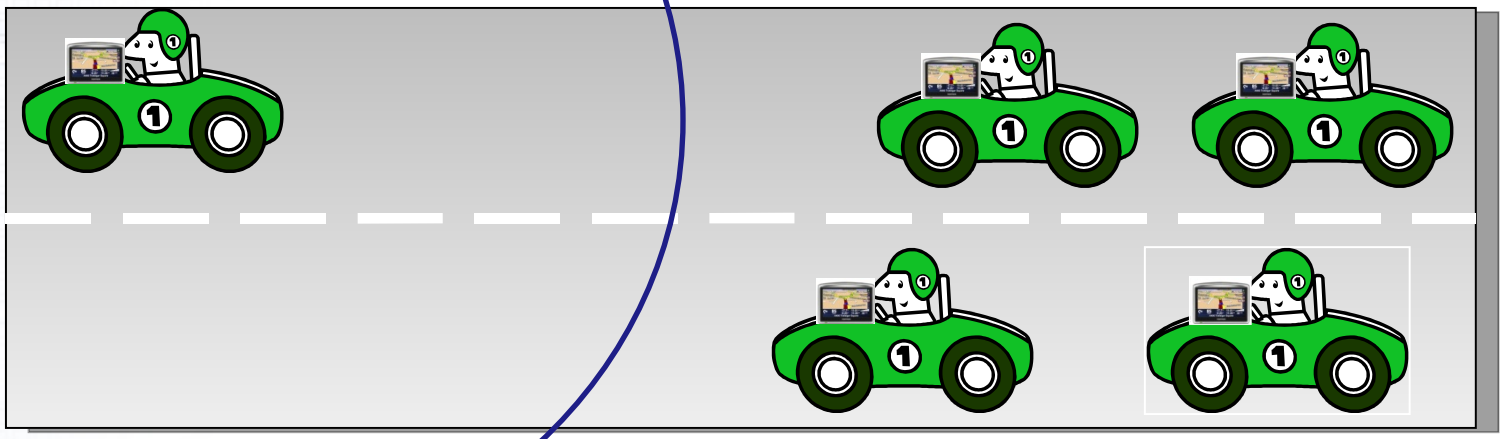
Discovery: Sparse



Sparse more common than dense –> “delay” tolerant protocol

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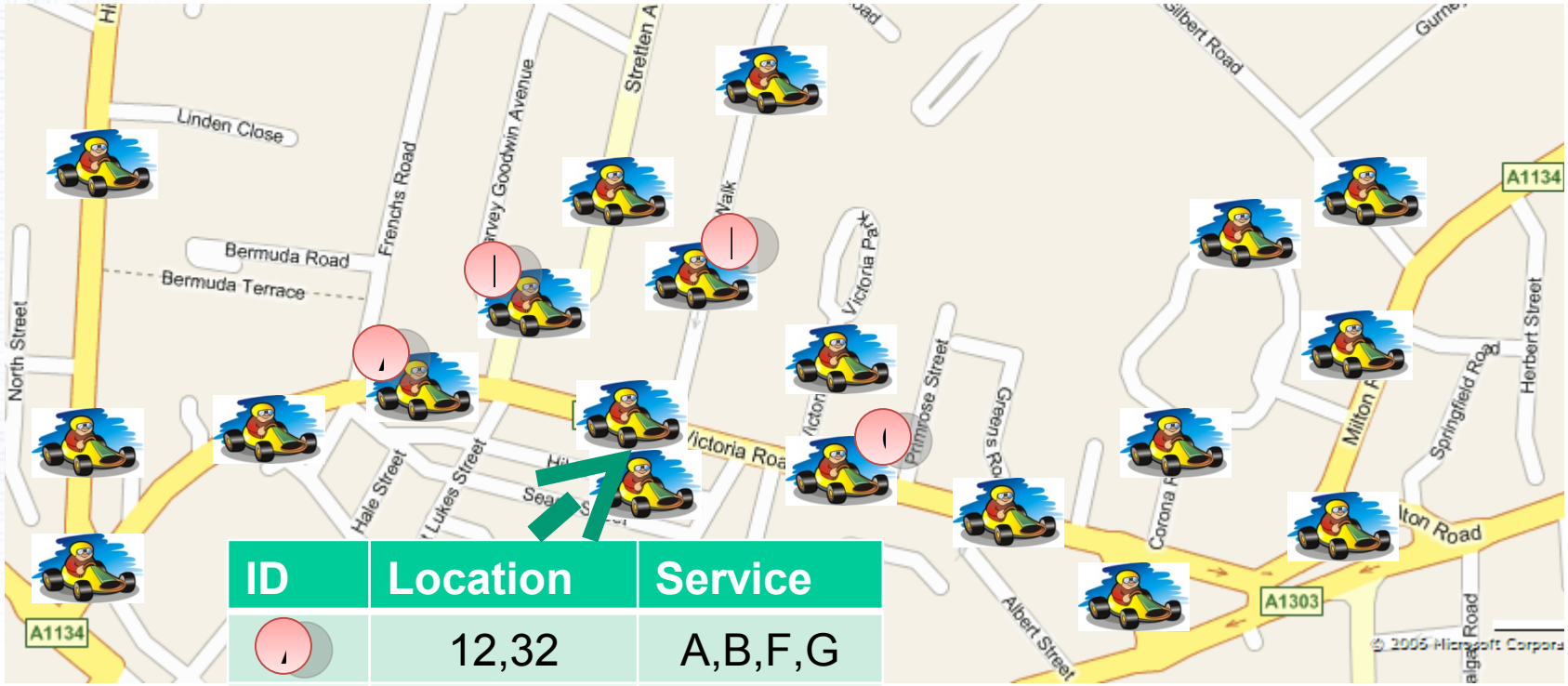
The PVRP approach

- Assume nodes have:
  - Digital maps (e.g. NavTech digital maps)
  - 802.11a/b/g WiFi (or equivalent)
  - GPS system

- Perform routing and discovery in map space not physical topology
  - Opposite to VRR

Assume nodes maintain one-hop topology information



ID	Location	Service
A	12,32	A,B,F,G
B	34,23	Q,R,F, S
C	18,38	A,B
D	45,34	A,B,G

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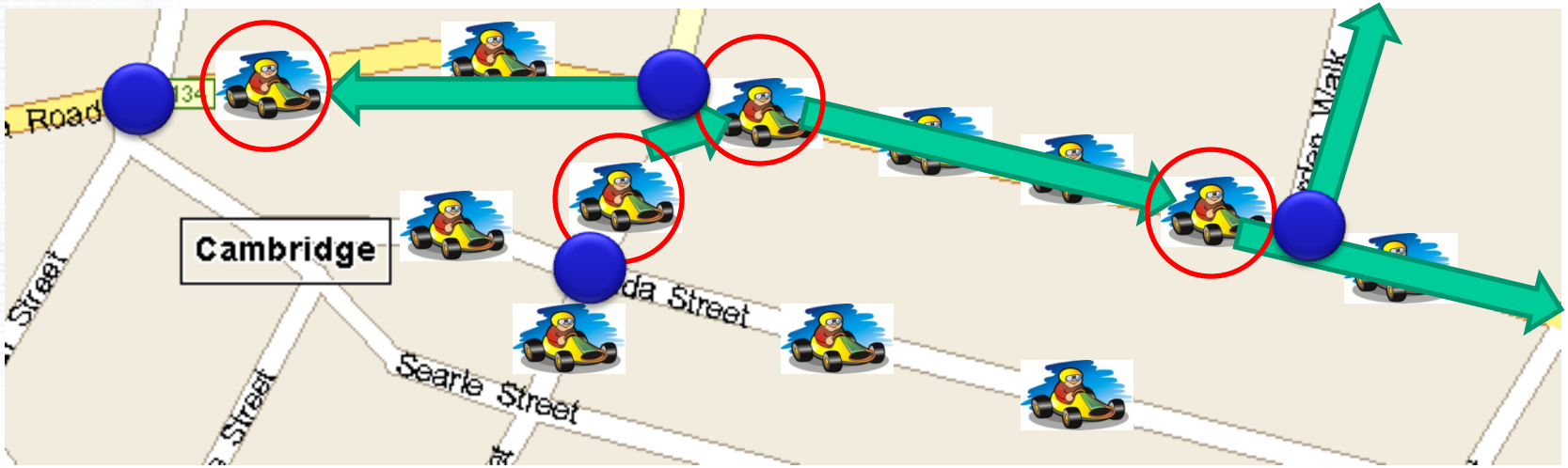
Discovery: Exploit map

- Avoid pure flood in physical topology
- Exploit map to ensure good exploration



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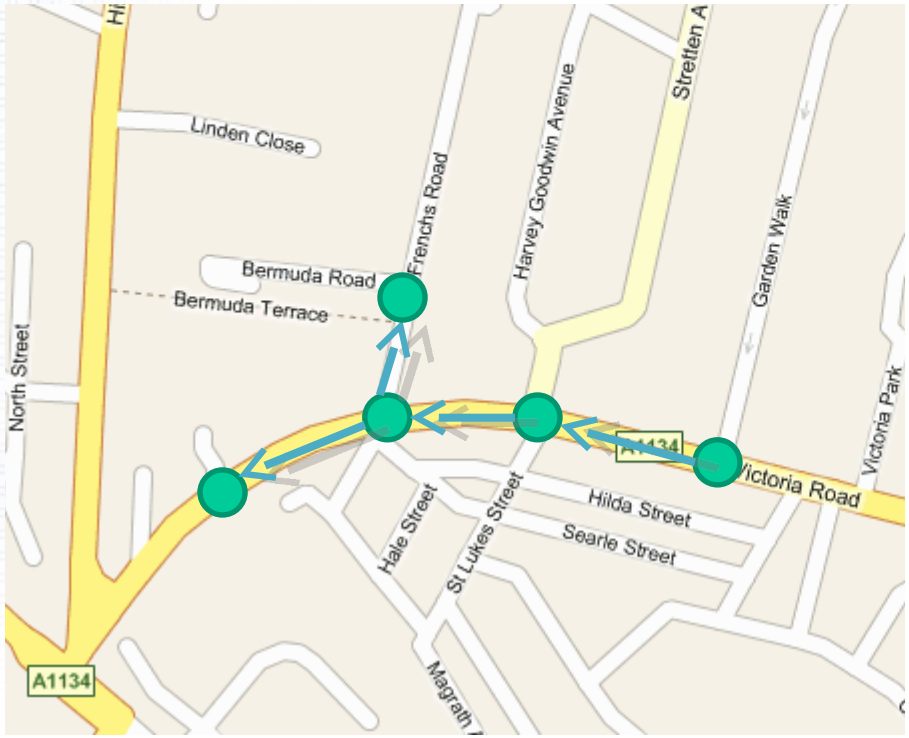
Map-based source routing



Packet: <Src> <Dest> <etc>
<Path:
Victoria Road -> Garden Walk Go W
Victoria Road -> Harvey Avenue Go W
Victoria Road -> Frenchs Road Go SW
>

Packet: <Src> <Dest> <etc>
<Path:
Victoria Road -> Garden Walk Go W
Victoria Road -> Harvey Avenue Go W
Victoria Road -> Frenchs Road Go N
>

Note: Between any two Junctions the packet may traverse several network hops

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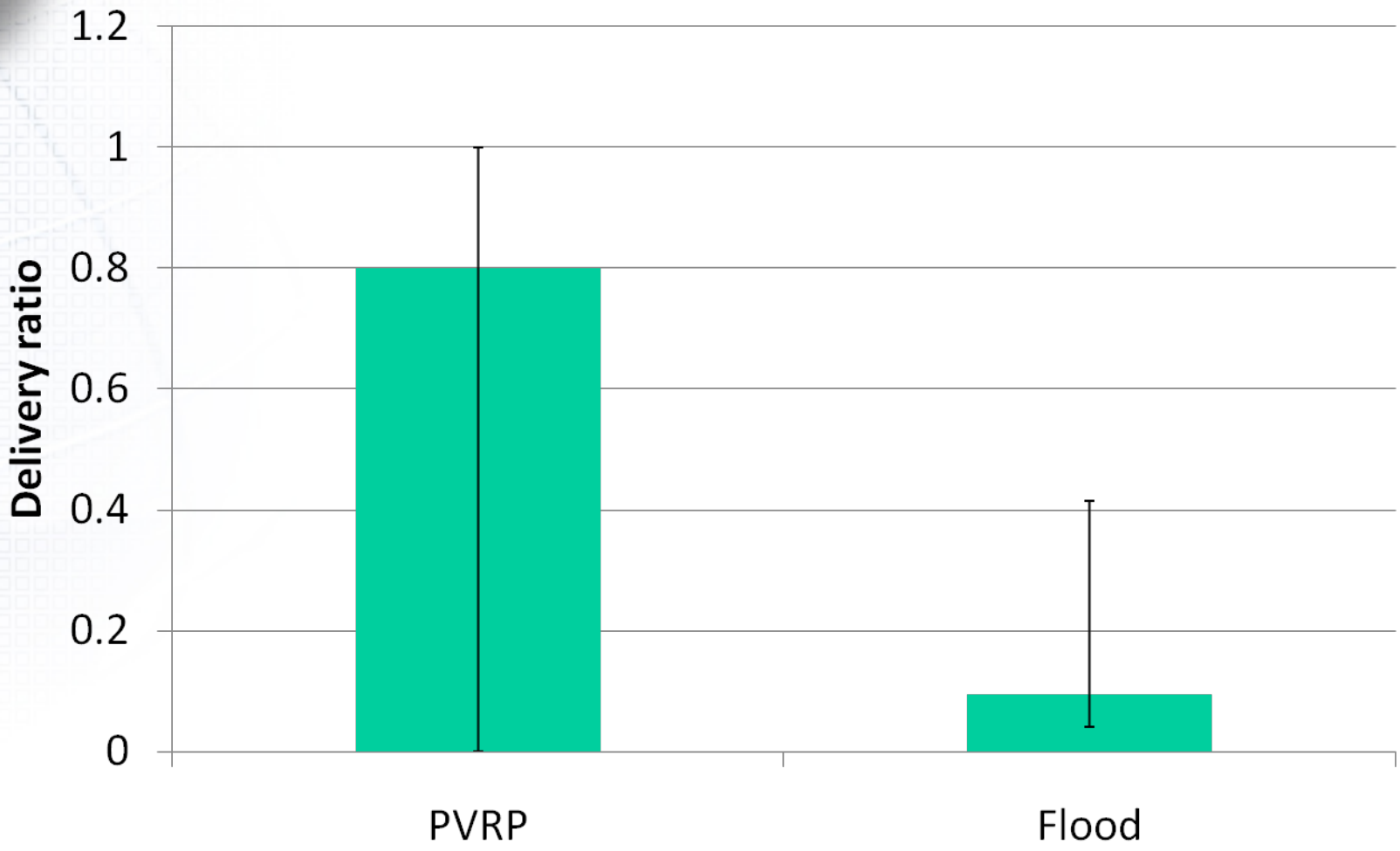
Preliminary results

- Currently understanding the design choices and their impact:
  - Path selection metrics:
    - Average density,
    - Max lowest density, etc
  - Junction selection metrics:
    - Select the important junctions
    - Comparing against delay tolerant greedy algorithm

Preliminary results

- Currently evaluating PVRP using:
  - “Simple” simulator (versus Flood)
  - QualNet simulator (versus AODV/DSR/GPSR)
  - Stand alone implementation (keeping us honest!)
- Using mobility traces for Portland
- Results today generated using simple simulator
  - Comparing PVRP with “Flood”
    - Flood represents best that AODV/DSR/GPSR could do
  - Results using “realistitc” mobility trace
    - 59 runs randomly selected static end-points with distance between 250m and 750m
    - Across all runs only 27 experiments delivered packets

Delivery ratio: Preliminary results



9 of 27 runs zero delivered

1 of 27 runs zero delivered

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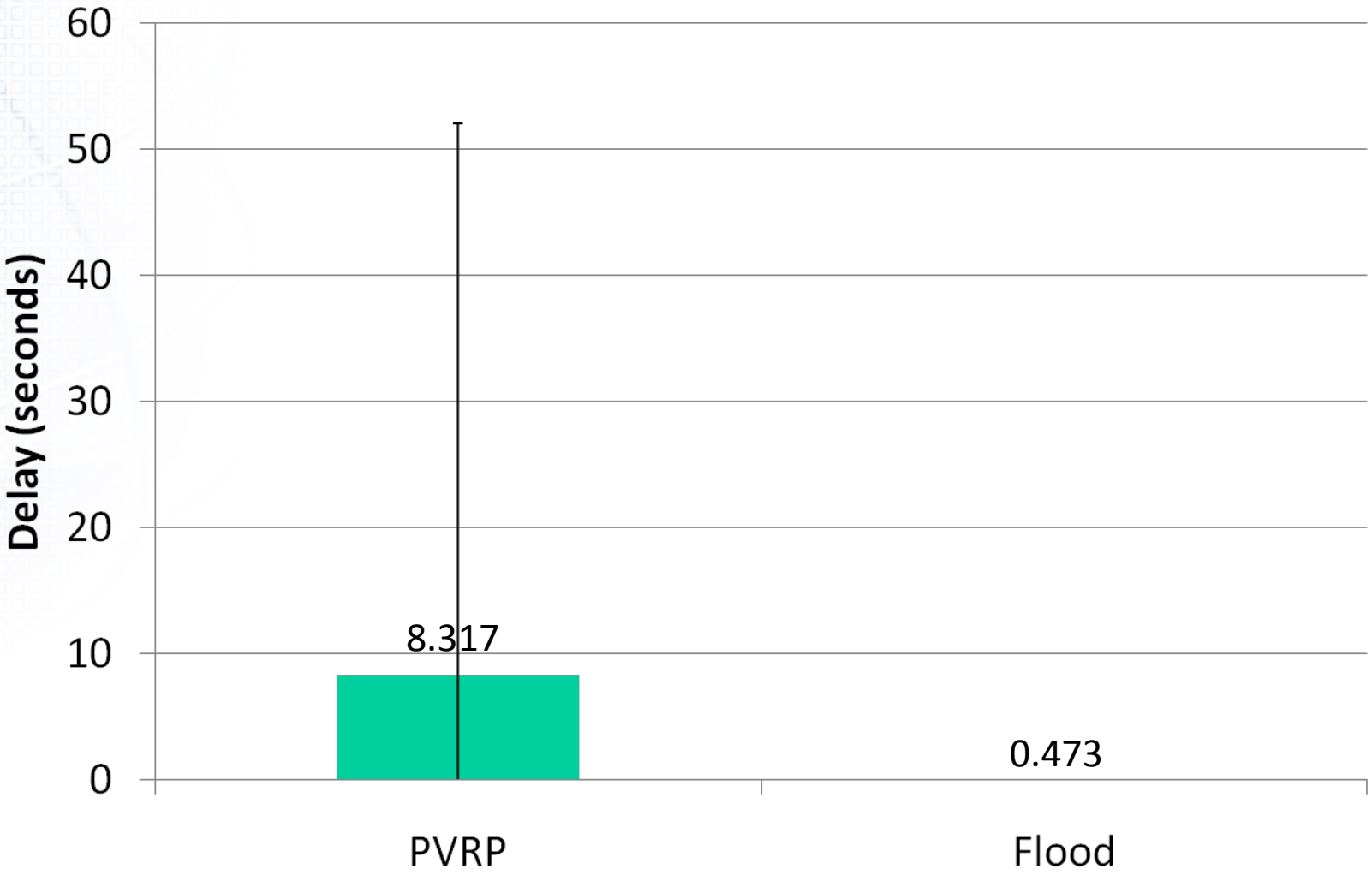
Delay: Preliminary results



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PVRP Summary

- Practical multi-hop routing protocol for vehicular networks
- Exploits digital maps rather than just the physical network topology
  - To work over partitioned networks

Thank you

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