CodeTorrent: Content Distribution using Network Coding in VANET

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Content Distribution in VANET

- Multimedia-based proximity marketing:
  - Virtual tours of hotel rooms
  - Movie trailers in nearby theaters
- Vehicular ad hoc networks (VANET):
  - Error-prone channel
  - Dense, but intermittent connectivity
  - High, but restricted mobility patterns
  - No guaranteed cooperativeness (only, users of the same interests will cooperate)
- How do we efficiently distribute content in VANET?
  - Traditional approach: *BitTorrent*-like file swarming

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BitTorrnet-like File Swarming

- A file is divided into equal sized blocks
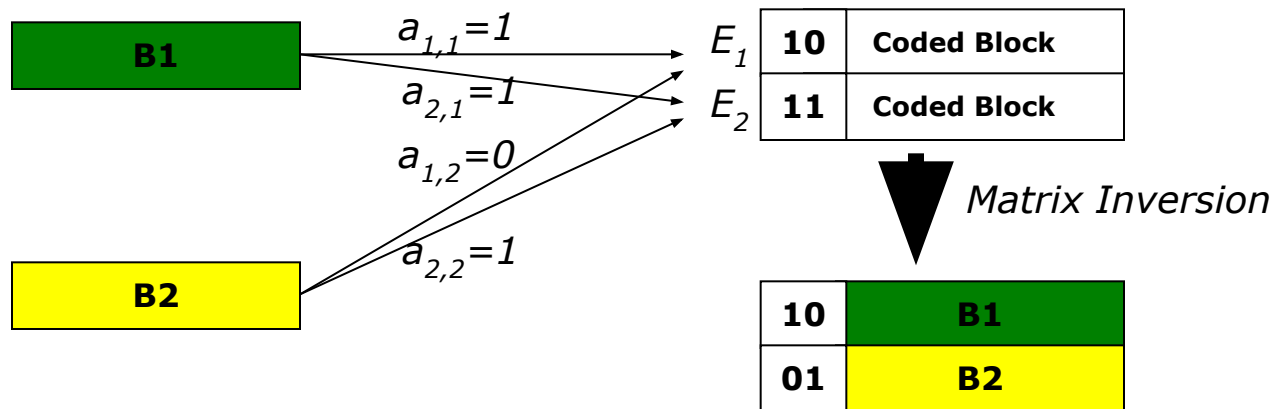- Cooperative (parallel) downloading among peers
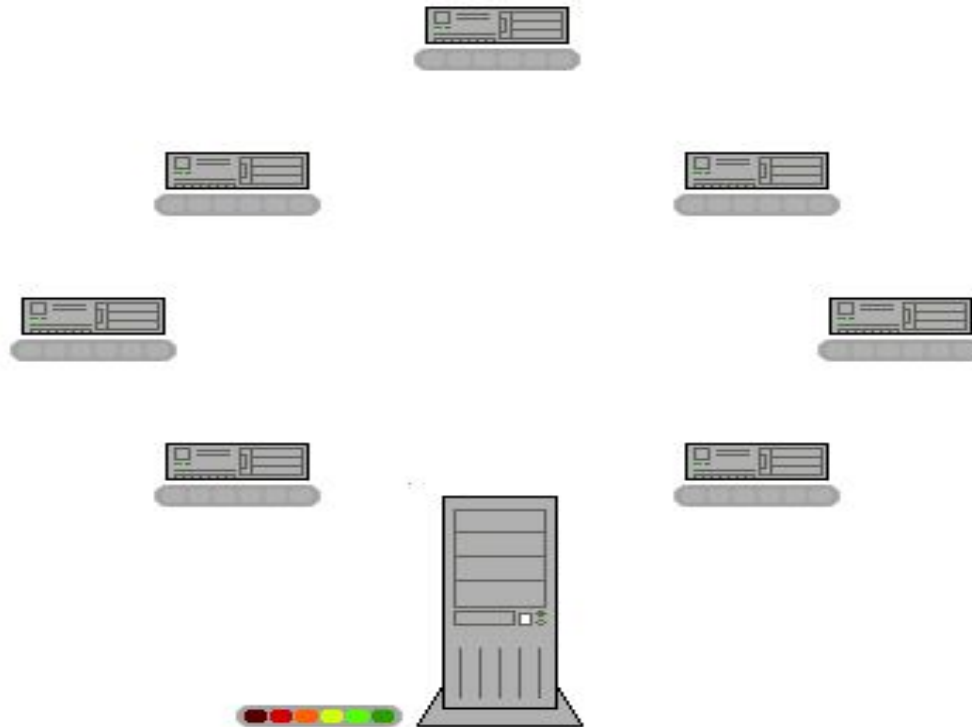
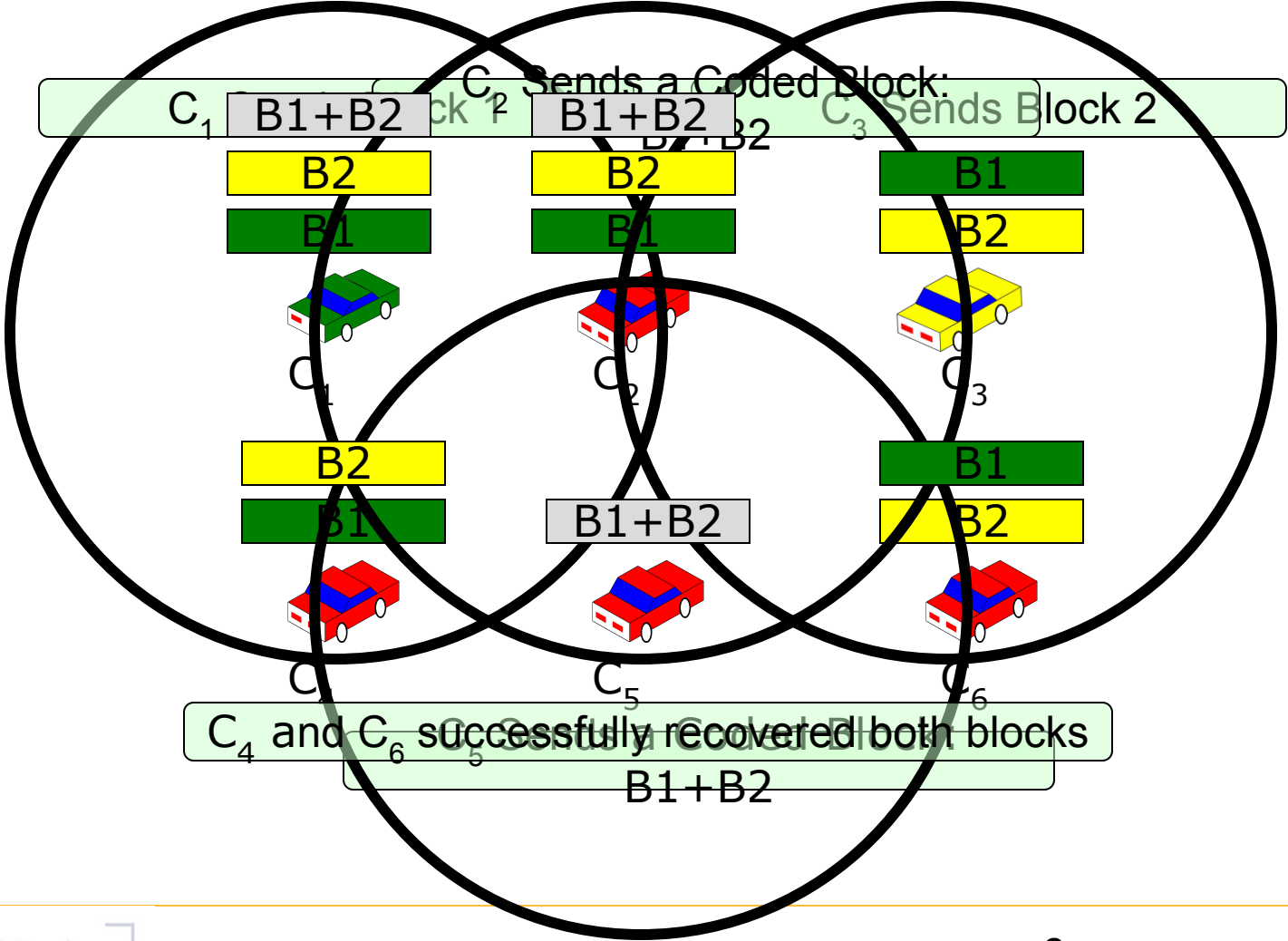# Swarming Limitation: Missing Coupon!
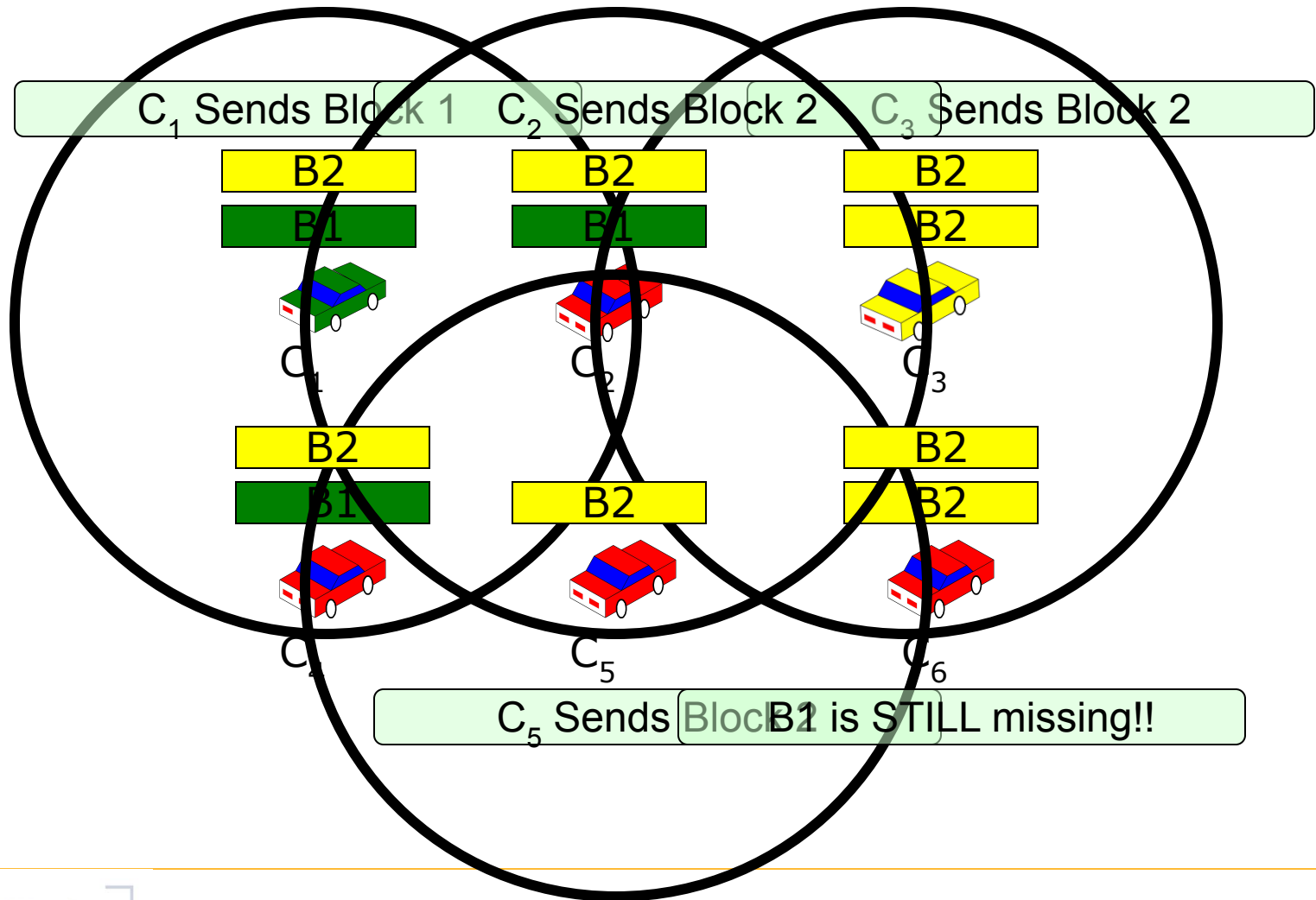
Network Coding

- Let a file has k blocks: $[B_1\ B_2\ _{...}\ B_k]$
- Encoded block E_i is generated by
  - $E_i = a_{i,1}*B_1 + a_{i,2}*B_2 + ... + a_{i,k}*B_k$
  - $a_{i,x}$: randomly chosen over the finite field
- Any "k" linearly independent coded blocks can recover $[B_1\ B_2\ _{...}\ B_k]$ by matrix inversion
- Network coding maximizes throughput and minimizes delay

Network coding over the finite field GF(2)={0,1}

Network Coding Helps Coupon Collection

C_1 Sends a Coded Block: B1+B2

C_2 Sends a Coded Block: B1+B2

C_3 Sends Block 2
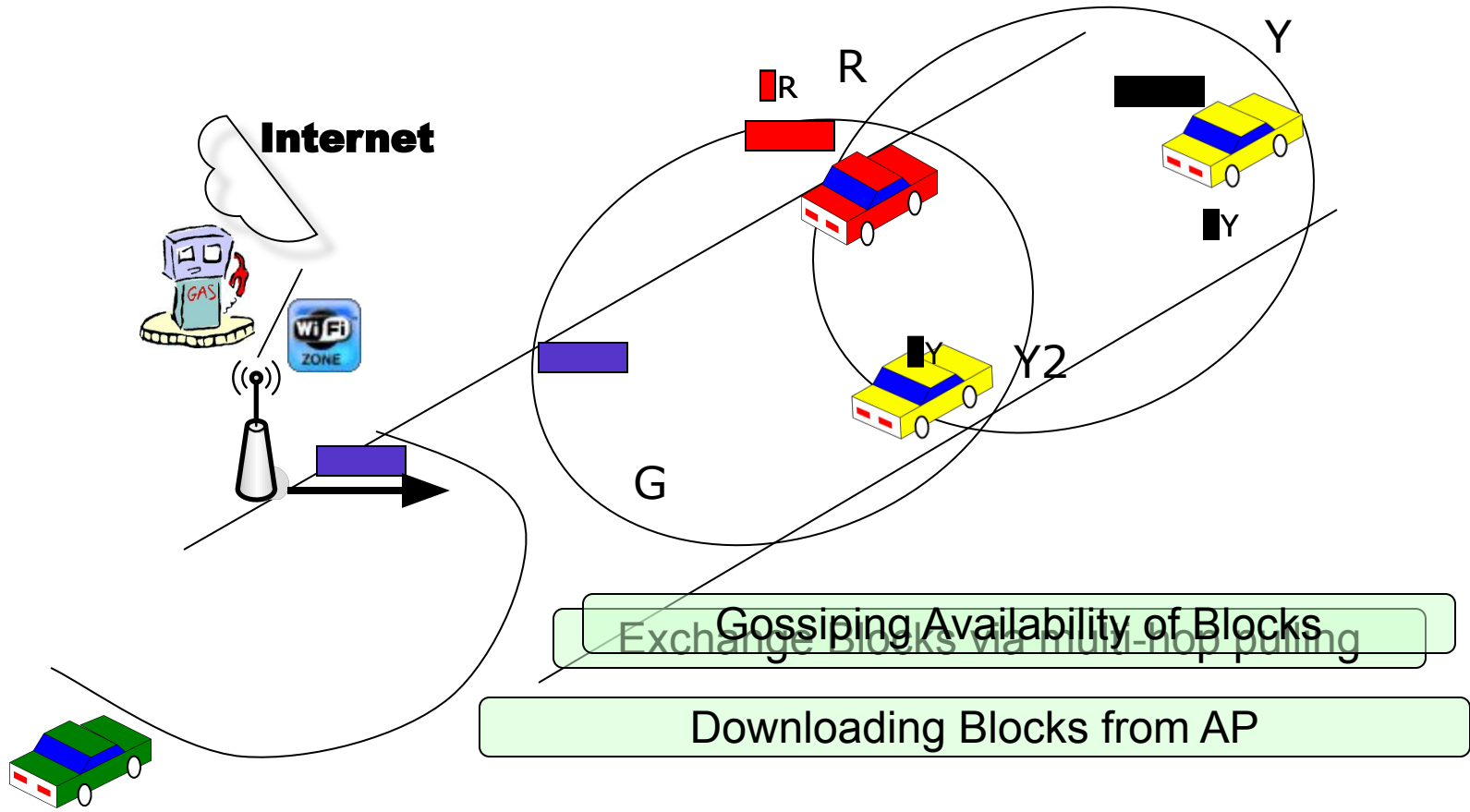
C_4 and C_6 successfully recovered both blocks

Outline

- Previous Work: *CarTorrent*
- Basic Idea
- *CodeTorrent*
- Simulation
- Conclusion

Previous Work: Cooperative Downloading with *CarTorrent*

Internet

R

R

Y

Y

G

Y2

Gossiping Availability of Blocks

Exchange Blocks via multi-hop pulling

Downloading Blocks from AP

CodeTorrent: Basic Idea

☐ **Single-hop pulling (instead of *CarTorrent* multihop)**

Internet

Buffer

Buffer

Buffer

File: **k** blocks

B1	$*a_1$
B2	$*a_2$
B3	$*a_3$
	$*a_k$
B*k*	

"coded" block

Random Linear Combination

Re-Encoding: Random Linear Comb. of Encoded Blocks in the Buffer

Outside Range of AP

Exchange Re-Encoded Blocks

Downloading Coded Blocks from AP

Meeting Other Vehicles with Coded Blocks

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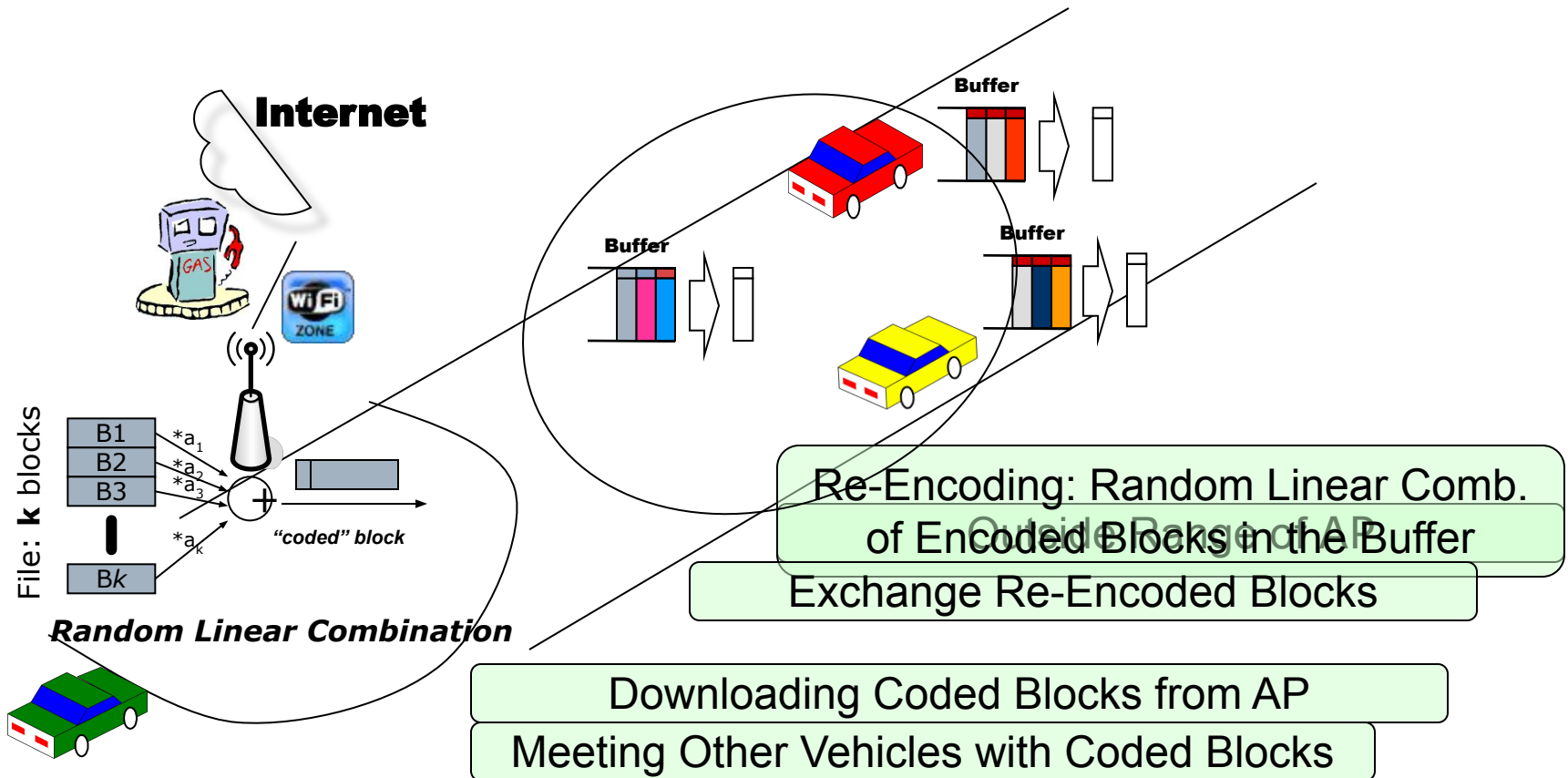
Design Rationale

- Single-hop better than multihop
  - Multi-hop data pulling does not perform well in VANET (routing O/H is high)
  - Users in multi-hop may not forward packets not useful to them (lack of incentive)!
- Network coding
  - *Mitigate* a rare piece problem
  - *Maximize* the benefits of overhearing
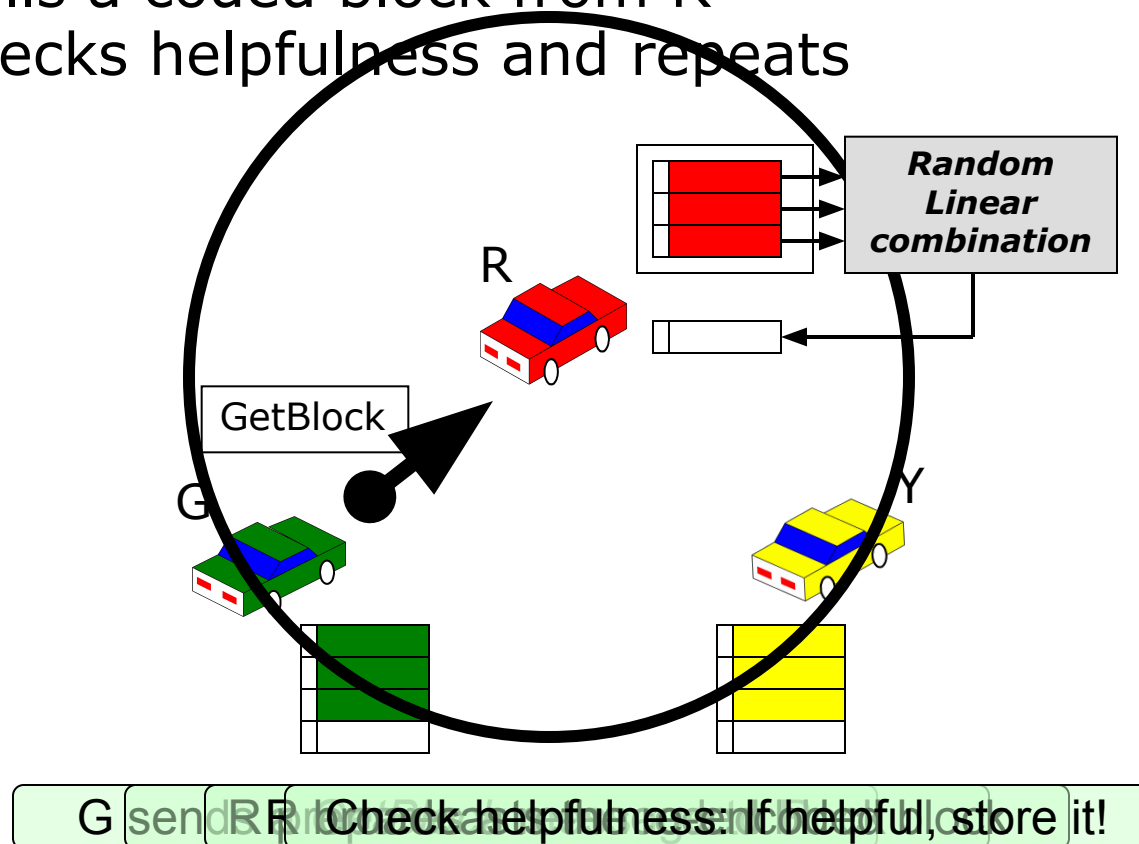- Exploits mobility
  - Carry-and-forward coded blocks

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CodeTorrent - Beaconing

- Periodic broadcasting of peer ID and its code vector
- Used for searching helpful nodes: those who have at least one linearly independent code block

Red is Helpful!

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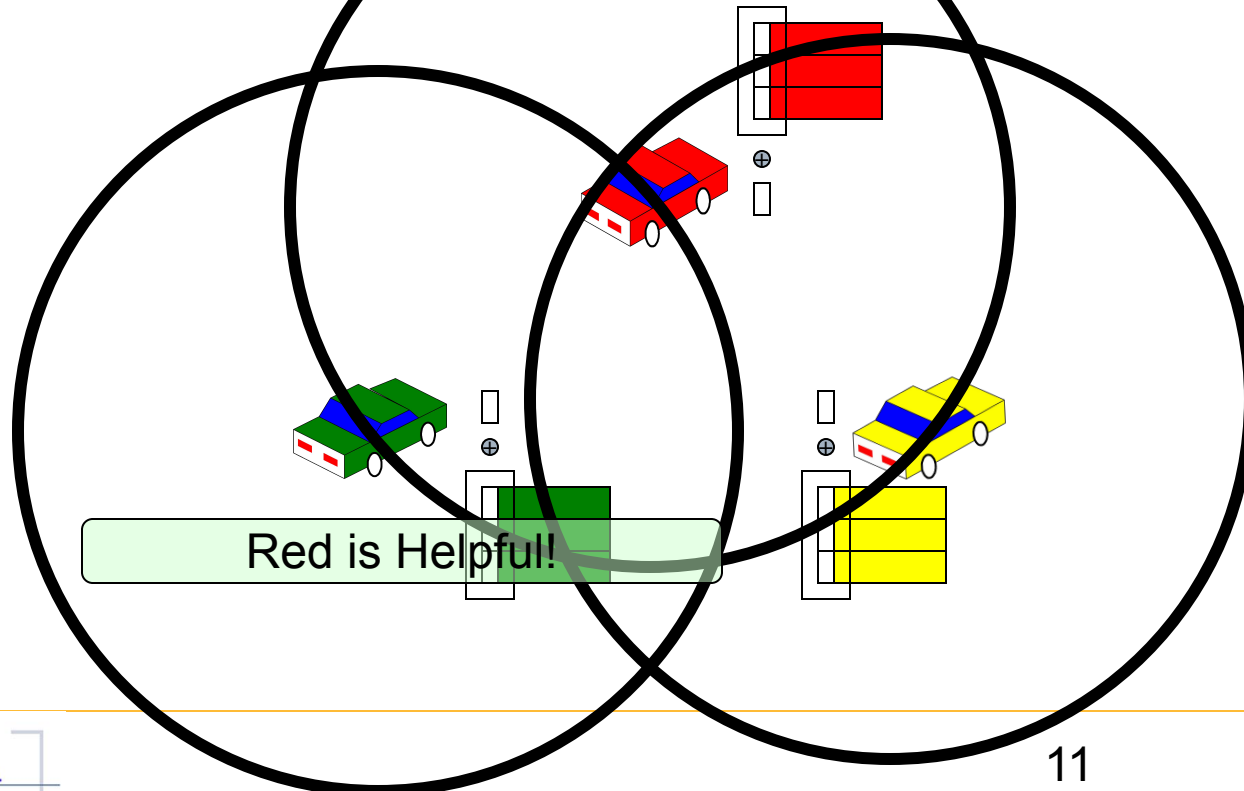
CodeTorrent - Single-hop pulling

☐ A peer pulls coded blocks from the helpful peers
  1. G pulls a coded block from R
  2. G checks helpfulness and repeats

Random Linear combination

R

GetBlock

G

Y

G send R request (Start to pull a single block) Check helpfulness: If helpful, store it!

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Simulations - Setup

- Qualnet 3.9
- IEEE 802.11b / 2Mbps
- Real-track mobility model (Westwood map)
  - 2.4x2.4 km^2
- Distributing 1MB file
  - 4KB/block * 250 blocks
  - 1KB per packet
- # of APs: 3
  - Randomly located on the road sides
- Comparing *CarTorrent* (w/ AODV) with *CodeTorrent*
  - AODV w/ net-diameter 3 hops
  - *CodeTorrent* with GF(256)
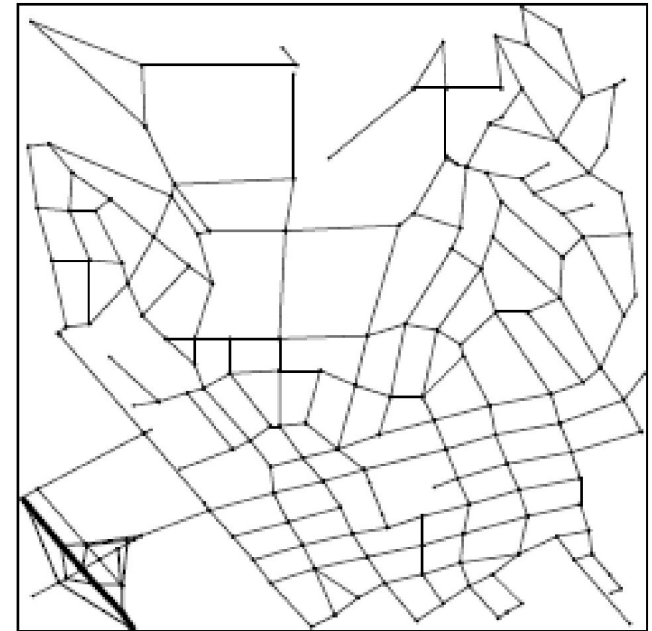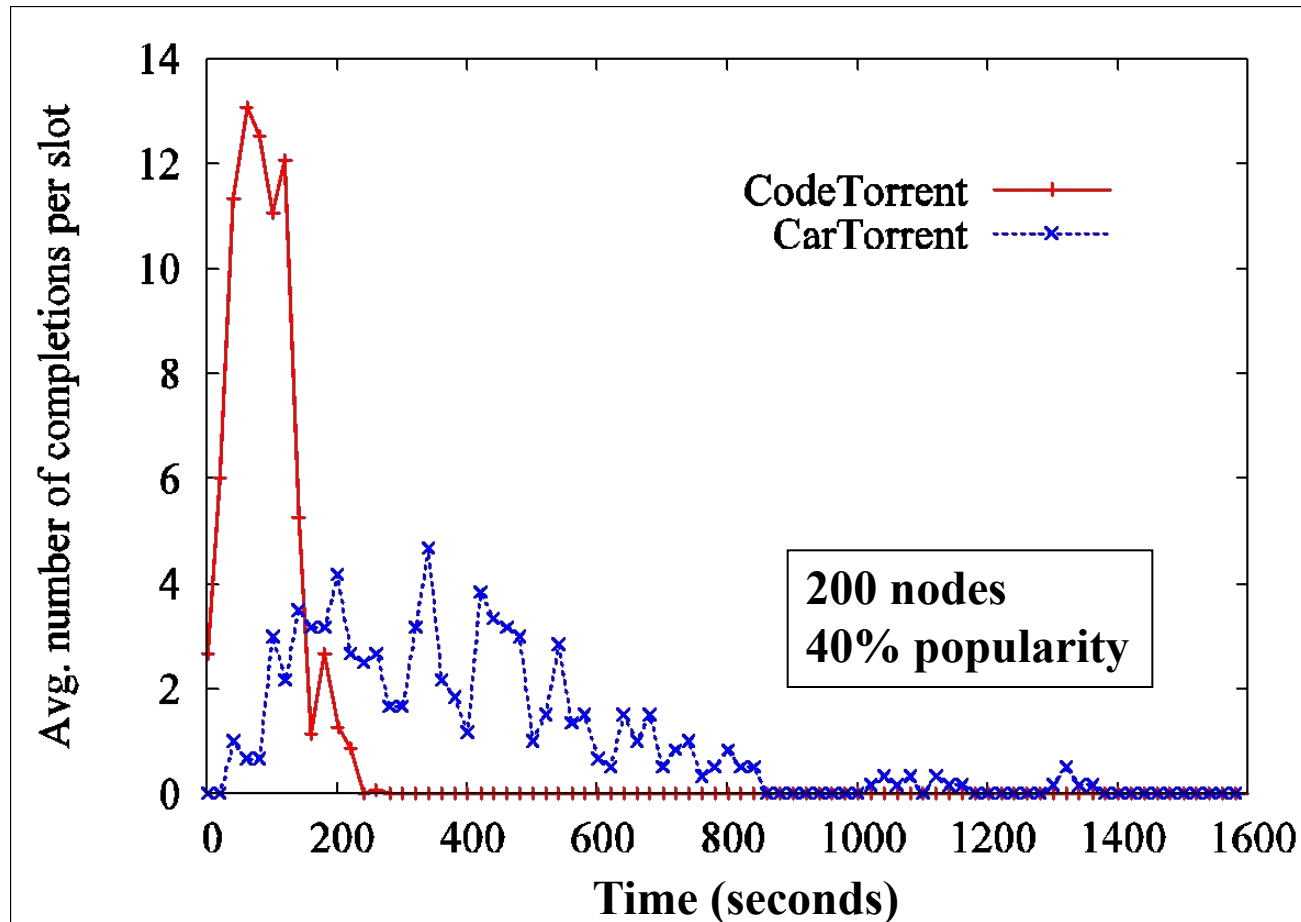

Near UCLA Campus
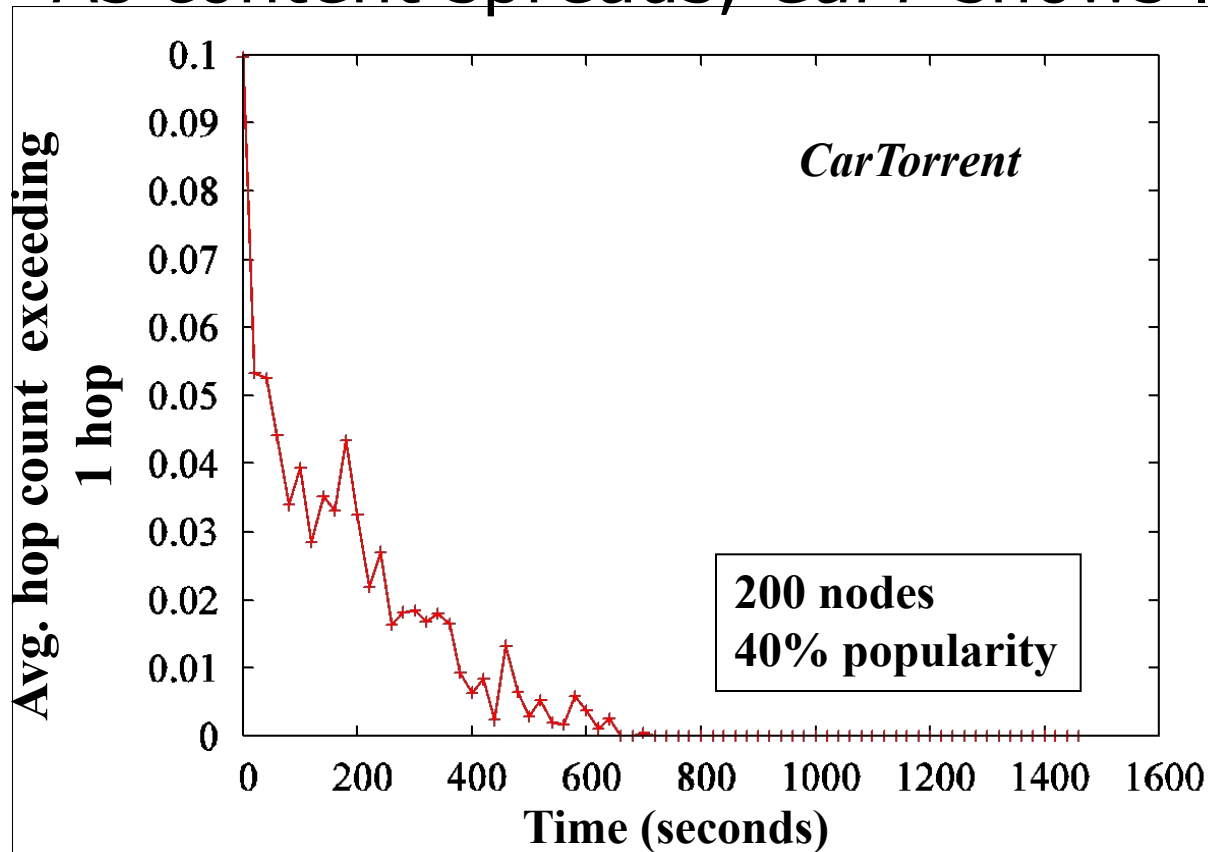
Simulation Results

☐ Overall downloading progress
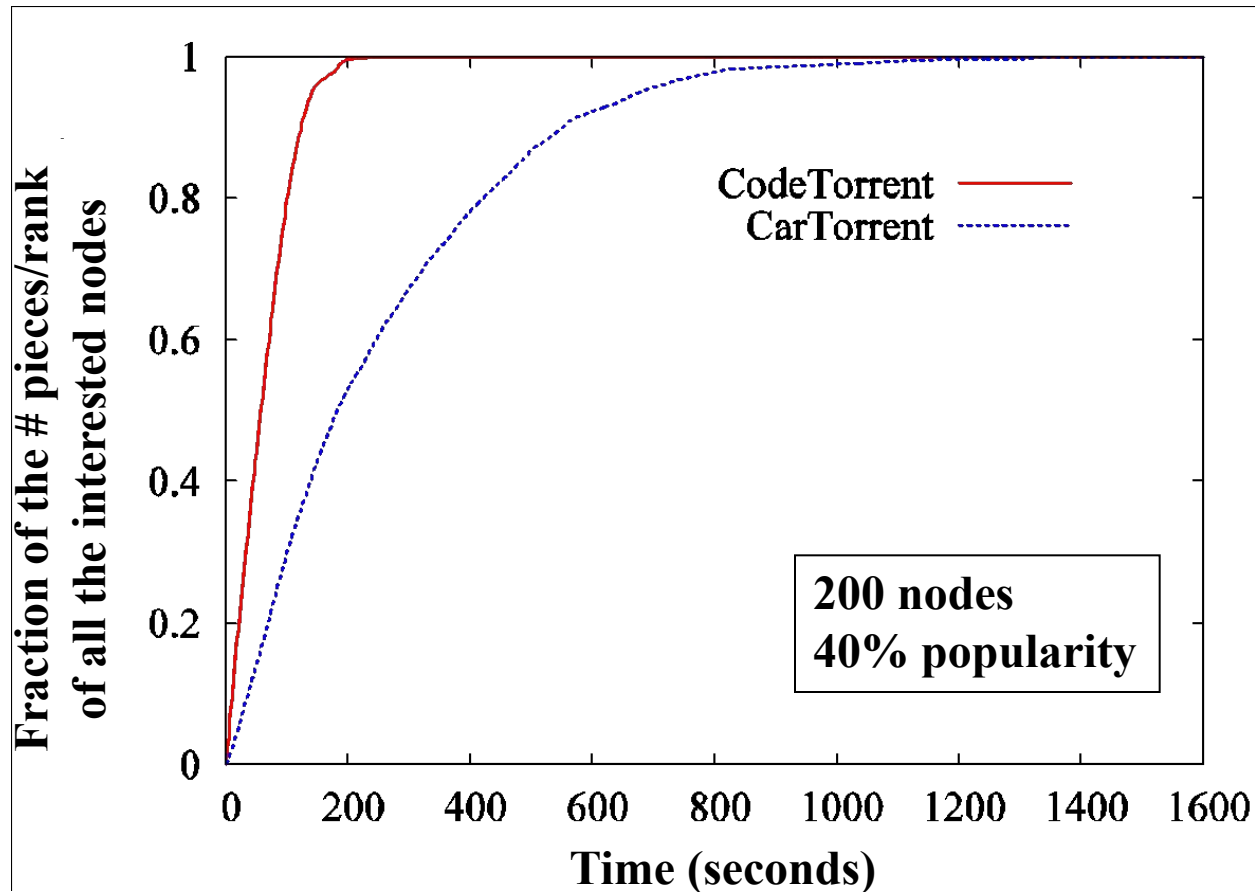
Simulation Results

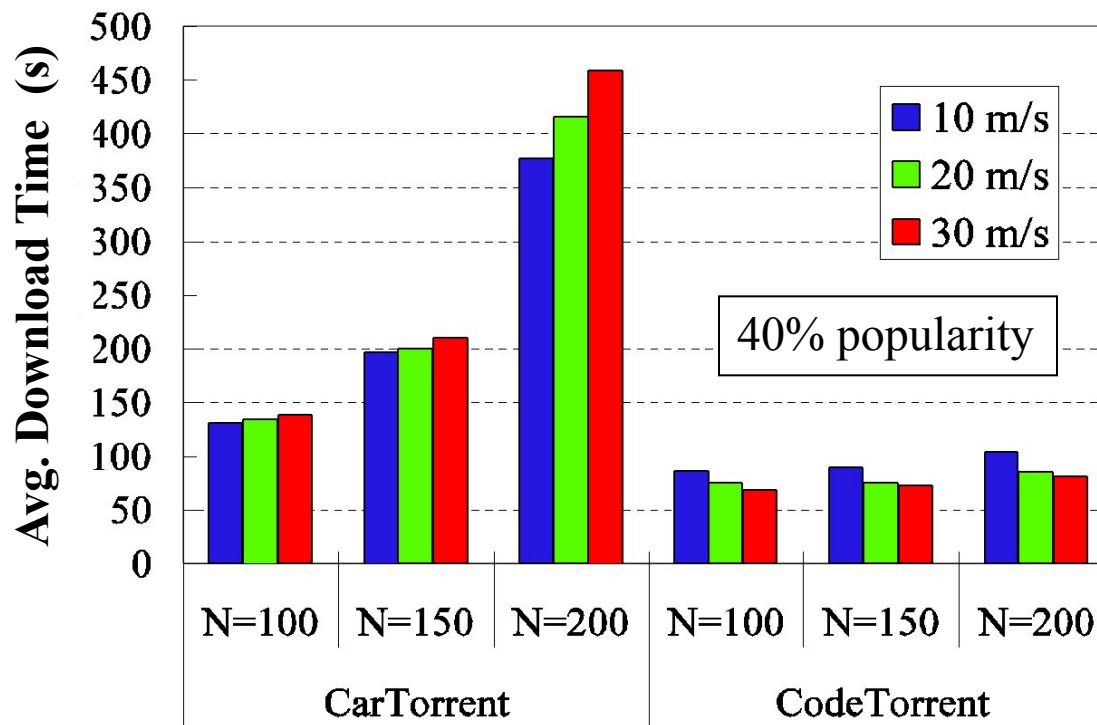☐ Avg. number of completion distribution

Simulation Results

☐ Multi-hop pulling in *CarTorrent*

■ As content spreads, *CarT* shows locality

Simulation Results

□ Impact of mobility

- ■ Speed helps disseminate from AP's and C2C
- ■ Speed hurts multihop routing (*CarT*)
- ■ Car density+multihop promotes congestion (*CarT*)

Conclusion

- Multihop-based *CarTorrent*:
  - Not scalable due to routing overhead
  - Cooperation may be a problem
  - Coupon problem
- *CodeTorrent:*
  - Scales to ***mobility***; favors cooperation; eliminates a coupon problem
- Future work
  - Modeling the impact of mobility
  - *CodeTorrent* testbed

Simulation Results

☐ Novelty of coded blocks

■ As speed increases, novelty improves