Content Distribution in VANETs using Network Coding: The Effect of Disk I/O and Processing O/H

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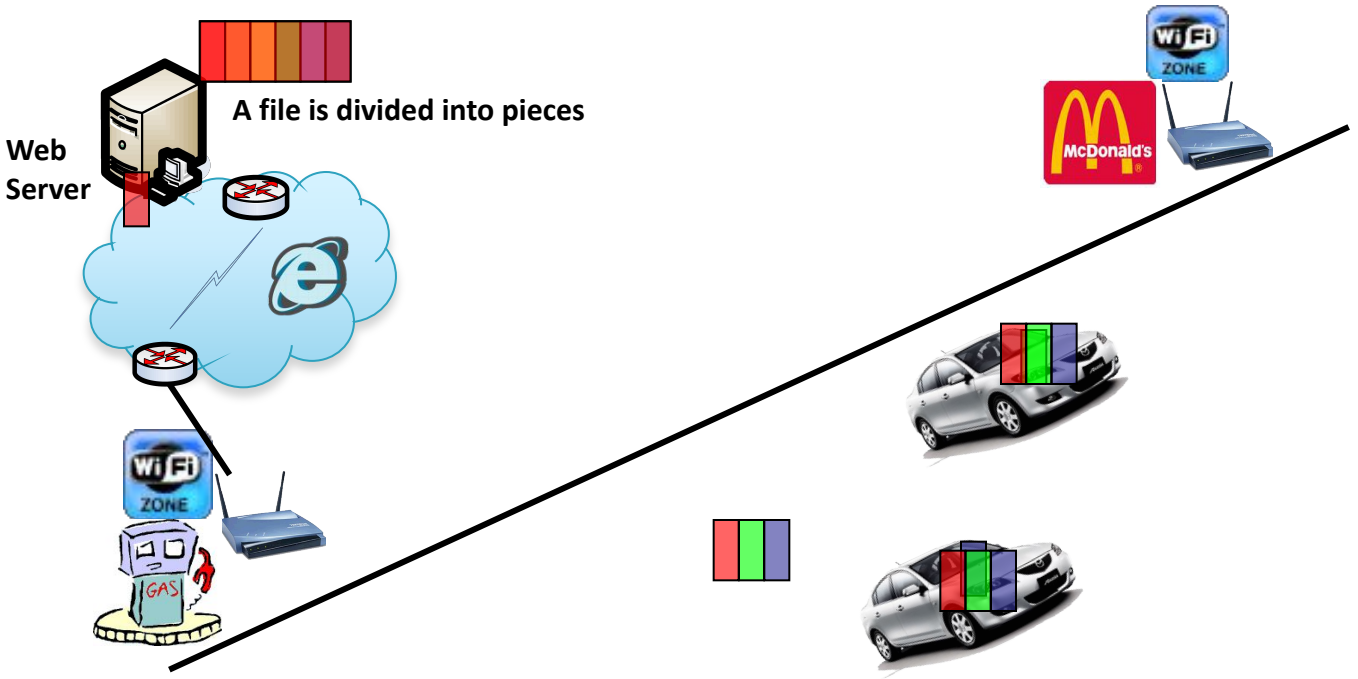
Content Distribution in Vehicular Ad-Hoc Networks (VANETs)

- Applications
  - Software updates and patches (e.g., navigation map, games)
  - Multimedia data downloads (e.g., videos, news, etc.)

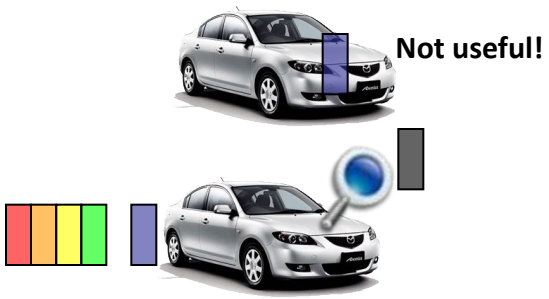
Content Distribution Challenges

- High mobility (i.e., highly dynamic networks)
- Error-prone channel (due to obstacles, multi-path fading, etc.)

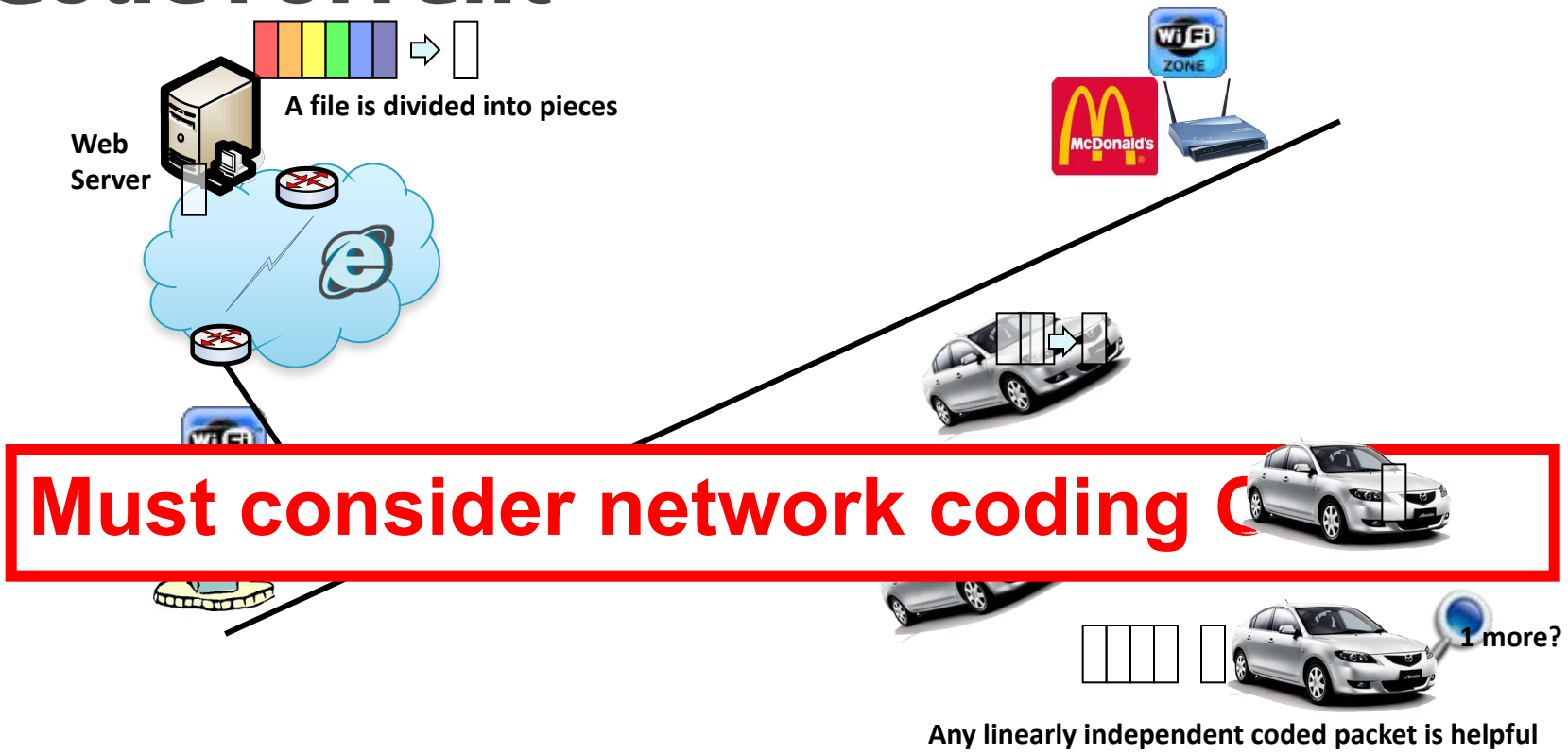
CarTorrent: BitTorrent-like Cooperative Content Distribution in VANETs



- Problem: Peer & Piece selection
  - coupon collection problem

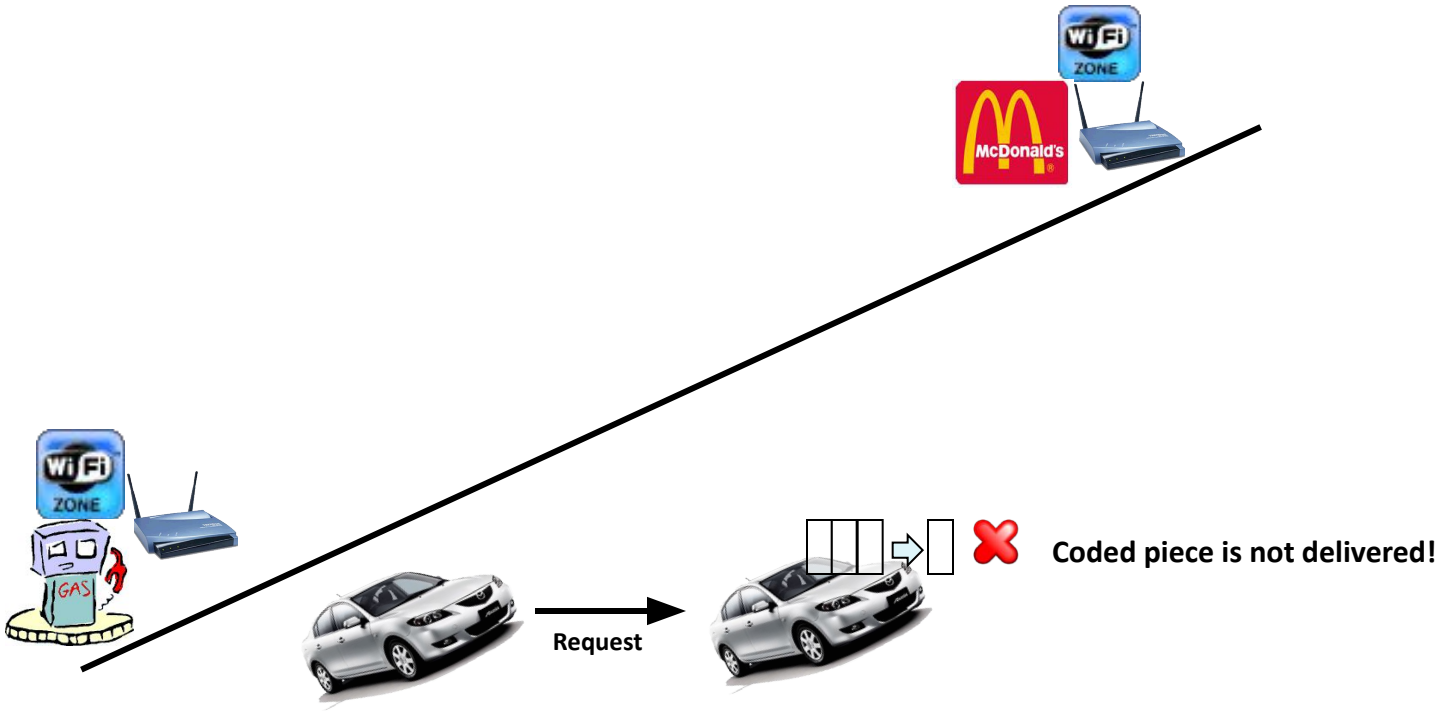


Using Network Coding: CodeTorrent



- Network coding “effectively” mitigates the peer/piece selection problem and “improves” the performance!

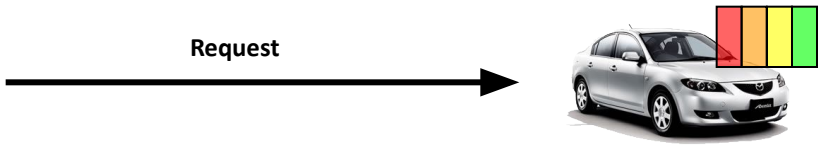
Worst Case Scenario



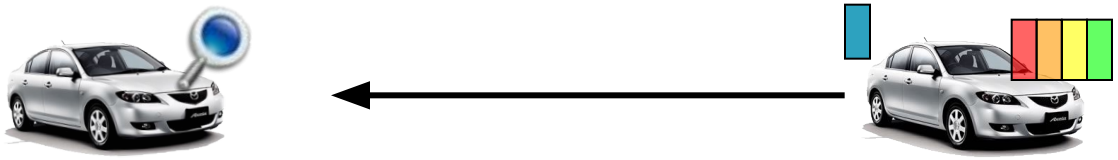
Network coding must be carefully configured!

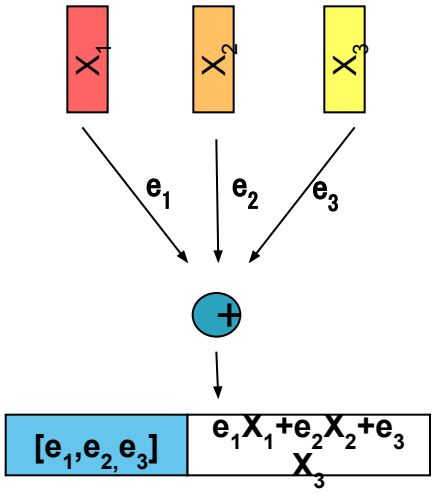
Should investigate "origin" of network coding O/H!!

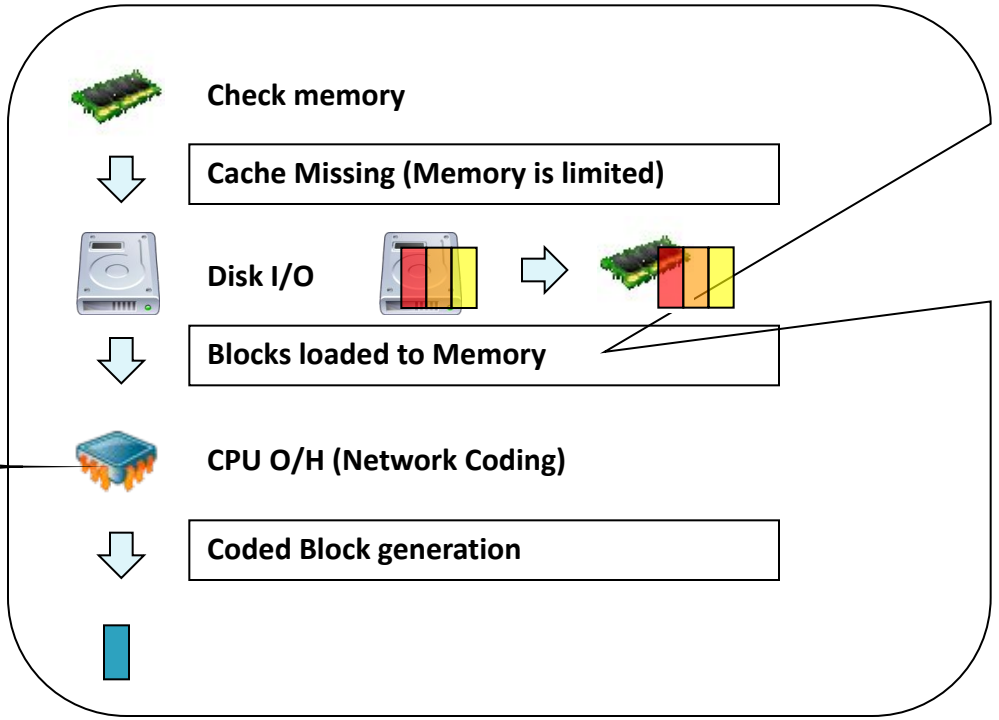
Closer Look at Network Coding O/H



Closer Look at Network Coding O/H

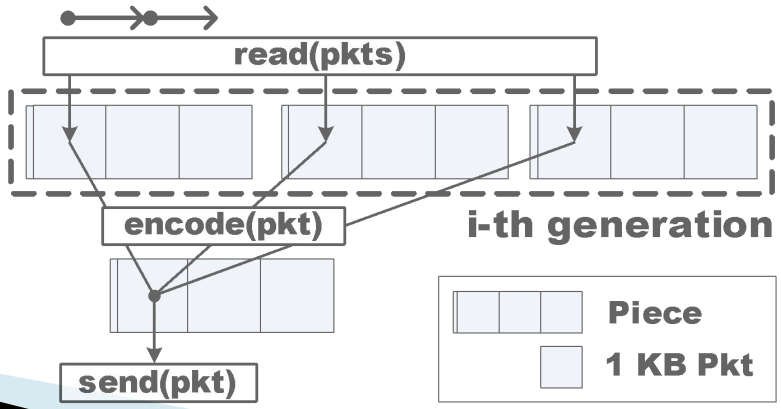






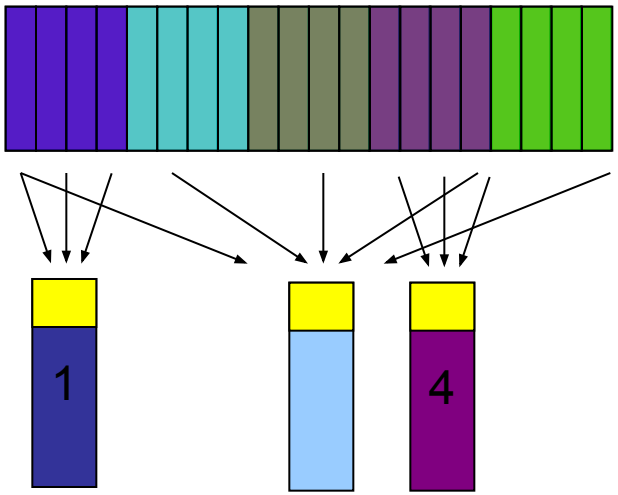
Network Coding O/H Model

- Overall process: **Reading** (cache miss) → **Encoding** → Sending
- Parallelization is feasible: Send an encoded "packet" ASAP
- Disk access O/H:
  - Must read all the necessary data before encoding
  - Disk input rate is determined by the characteristics of a disk
  - O/H is proportional to the number of pieces to be encoded
- Encoding O/H
  - Per symbol encoding ($\Sigma e_i X_i$) O/H: Linearly proportional to the cost of a pair of Galois Field (GF) operations (multiplication & addition)
  - Encoding rate = (# pieces * GF <+,*> time)$^{-1}$
  - O/H is proportional to the number of pieces to be encoded



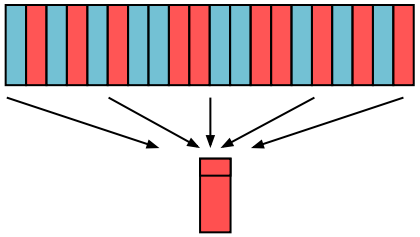
Mitigating Coding Overheads

- Solutiion#1: divide a file into small generations
  - Problem: too many generation causes a coupon collection problem
  - Conflicting goals: maximizing benefits of NC vs. minimizing coding O/H



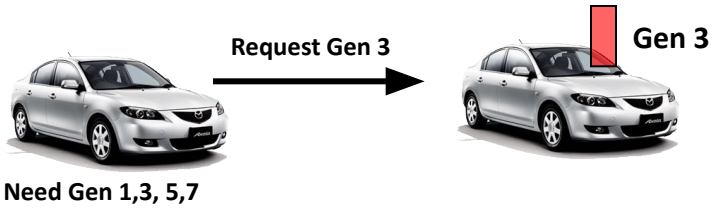
Mitigating Coding Overheads

- Sol#2: encode only a fraction of pieces (i.e., sparse coding)
  - Problem: how to find the right value?



Ex. Sparse Coding Rate: 50%

- Sol#3: pull a generation that is in the buffer of a remote node (remote buffer aware pulling)



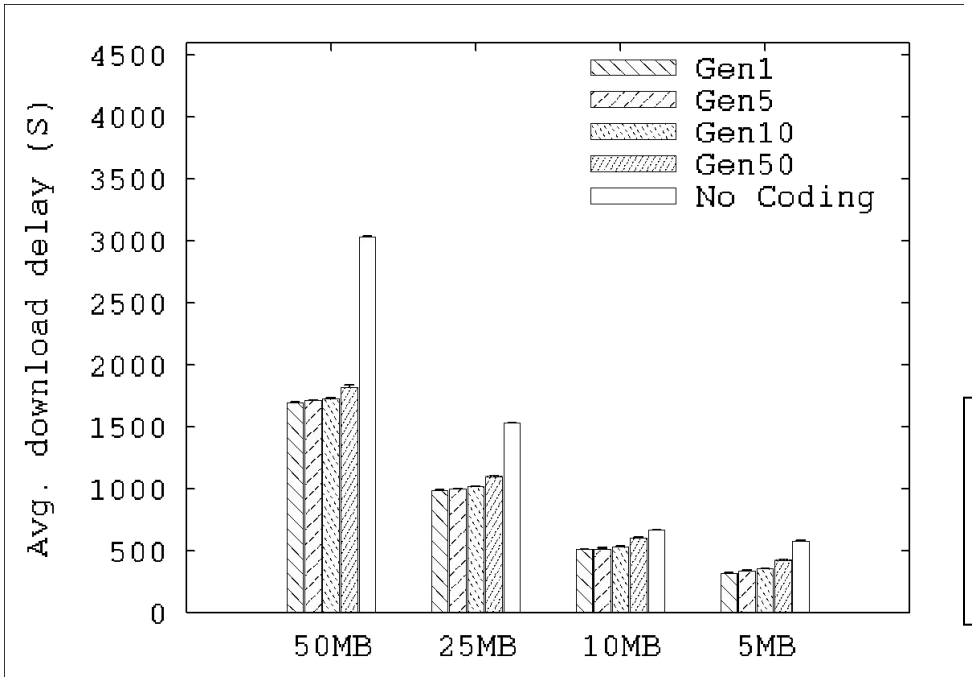
Evaluating Impacts of Coding O/H

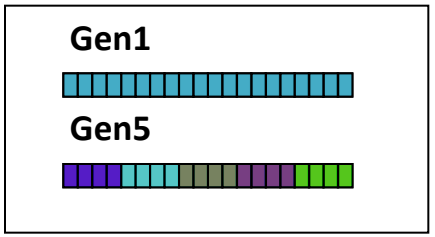
- Difficult to evaluate the overall impacts of coding O/H in VANETs
  - Dynamic nature of VANETs (high mobility)
  - Large scale scenarios
  - Network Simulator (e.g., NS2, QualNet) only models communication O/H
- Implement our measurement based models into a network simulator (QualNet)

Simulation Setup

- Communications
  - 802.11b; 11Mbps + Two-ray ground propagation
- Mobility
  - Real-track model w/ speed range of [0,20] m/s
  - UCLA area map: 2400m*2400m
- Nodes
  - 3 APs: file sources
  - 200 nodes/40% interest level:
    - 80 nodes are downloading a file
- O/H model
  - Coding rate: 7.6 Mbps
  - Disk I/O rate: 38 MB/sec

Simulation Results (1)

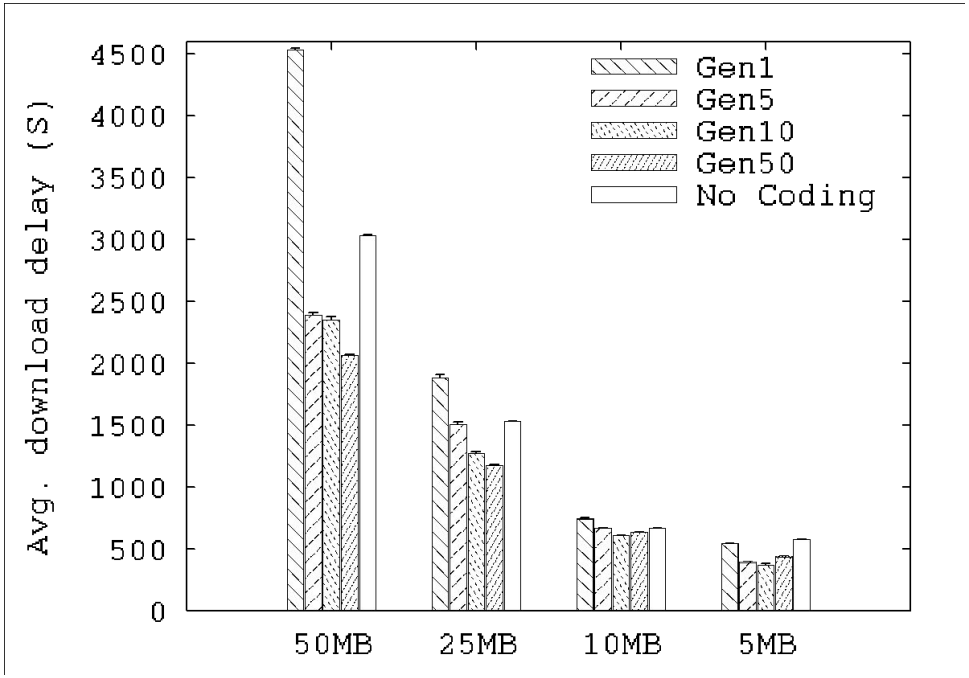




Delay without O/H

- Delay without O/H
  - Small # of generations is a better choice
  - Larger # of generations more severe coupon collection problem

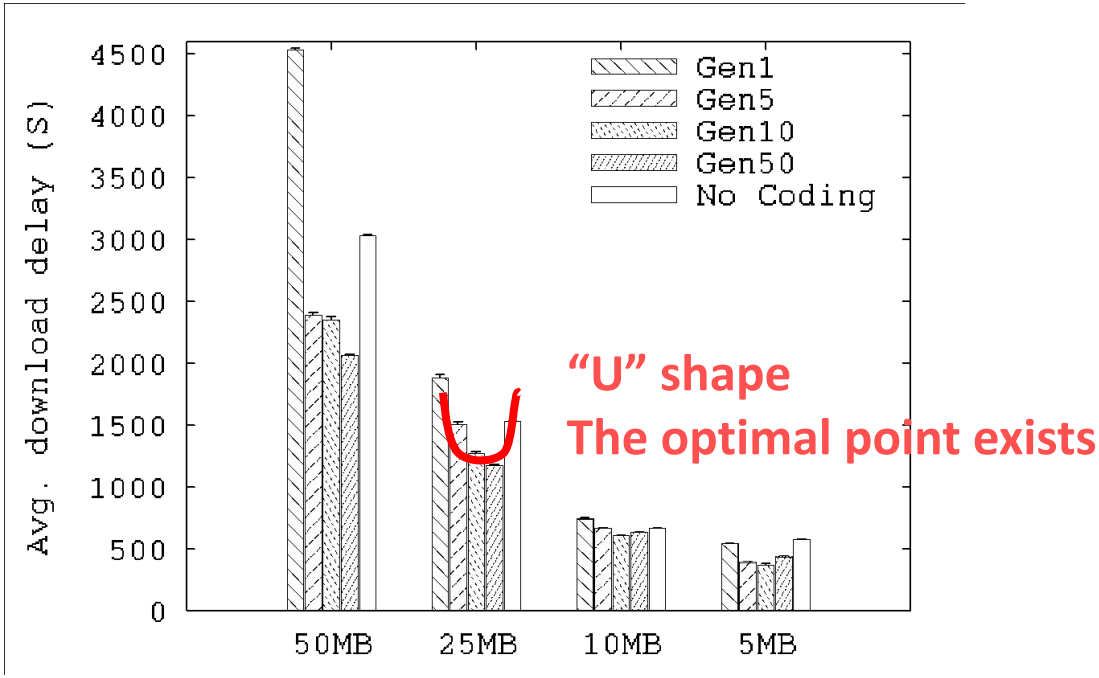
Simulation Results (2)



Delay with O/H (Buffer 50%)

- Delay with O/H (Buffer 50%: CPU O/H + Disk I/O)
  - Small # of generations is not a better choice any longer!!
  - Single generation scenario is even worse than “No coding” case.
  - Must carefully choose the number of generations!

Simulation Results (2)



Delay with O/H (Buffer 50%)

- Delay with O/H (Buffer 50%: CPU O/H + Disk I/O)
  - Small # of generations is not a better choice any longer!!
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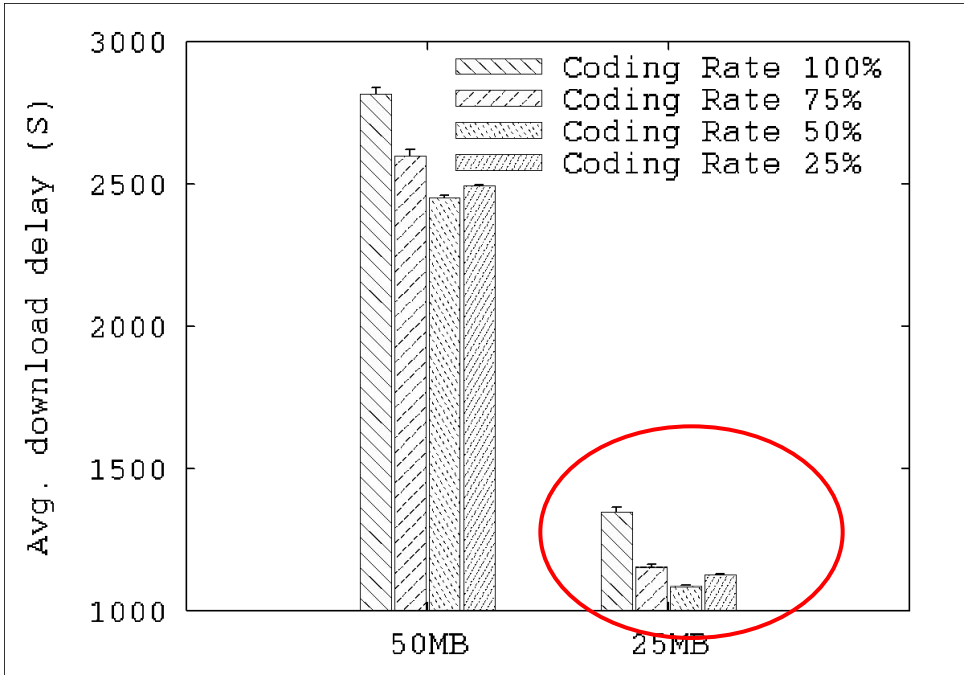
  - Must carefully choose the number of generations!

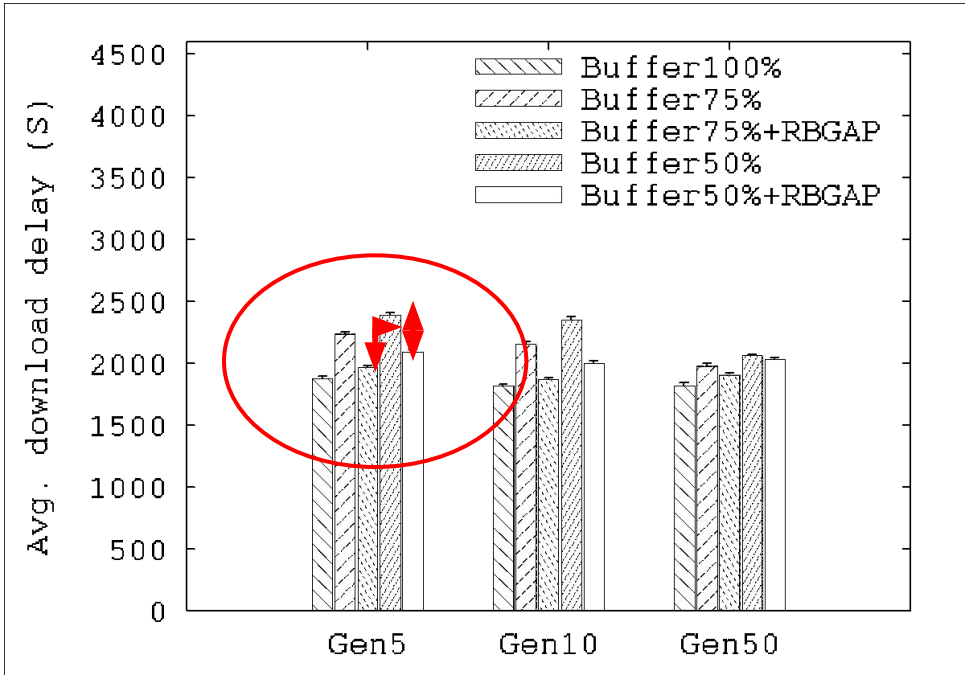
Simulation Results (3)



Delay with Sparse Coding (50MB)

- Sparse coding rate must be carefully chosen.

Simulation Results (4)



Delay with RBAP (50MB)

- Remote Buffer Aware Pulling (RBAP)
  - Successfully reduces disk I/O O/H

Conclusion

- Investigated the impacts of network coding O/H
  - Disk I/O + Processing O/H
- Designed “measurement” based models
- Evaluated various strategies to mitigate O/H
  - Multiple generations, sparse coding, buffer aware pulling
- ***Lessons learned:*** ***network coding must be carefully configured to maximize its benefits***
- Future work
  - **Good configuration? –** must tune various factors, i.e., piece size, disk access/coding rate, and shared bandwidth
  - Understand the impacts of O/H and study enhancement techniques (e.g., H/W acceleration) in various environments (e.g., embedded systems, Smart Phones)