Network Coding Aware Rate Selection in Multi-Rate IEEE 802.11

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Network Coding

- ❑Can combine packets before forwarding
- ❑Coded packets must be multicast
- ❑Uncoded packets may need to be overheard at neighbors, i.e., may need to be multicast
- ❑Network coding scheme based on "COPE"
  - ❑Overhear all transmissions in a neighborhood
  - ❑Track packets delivered to neighbors
  - ❑Fill gaps in packet delivery sequence efficiently by combining packets
  - ❑Only scan 1-hop neighborhood for coding opportunities
  - ❑Per-hop encoding and decoding
- ❑Traffic: Unicast
  - ❑Primarily leads to inter-flow coding
- ❑Note: Rate selection scheme proposed applies to any network coding scheme

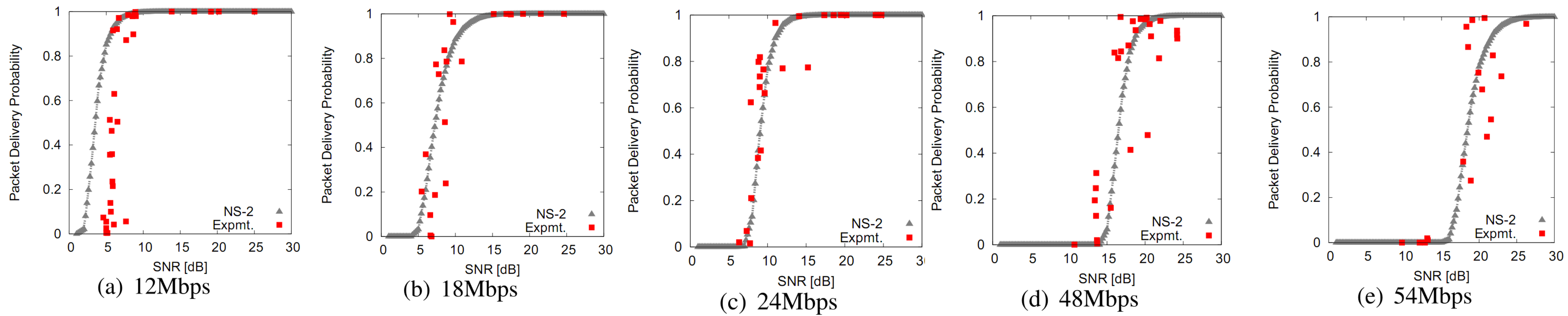
Rate Selection

- ❑A hyperarc may have multiple destinations of multiple types – direct, overhearing
- ❑Rate adaptation may select different transmission rates to different targets
- ❑Rate selection: Determine a single transmission rate for multicast to all hyperarc targets

- ❑Properties
  - ❑Should not preclude overhearing in a neighborhood (i.e., Overhearing Tradeoff)
  - ❑Should maximize goodput (i.e., application level throughput) to destinations (i.e., Multicast Tradeoff)

- ❑Objective : A rate selection algorithm to maximize goodput in a multi-hop multi-rate wireless network that uses network coding

Rate Adaptation – IEEE 802.11g



(a) 12Mbps (b) 18Mbps (c) 24Mbps (d) 48Mbps (e) 54Mbps

- ❑IEEE 802.11 (a/b/g) provides multiple transmission rates
  - ❑But does not specify a transmission rate adaptation scheme
- ❑Channel conditions over a link vary
- ❑Most rate adaptation schemes maximize hyperarc goodput
- ❑Measure channel conditions based on SNR of received packets

TRANSMISSION RATES AND RATE ADAPTATION FOR 1500BYTE PACKETS

Mbps	pps	SNR Range	Mbps	pps	SNR Range
6	376	≤ 3.77	24	905	9.99-15.61
9	508	NA	36	1071	15.61-18.40
12	616	3.77-8.90	48	1182	18.4-23.10
18	783	8.9-9.99	54	1222	> 23.10

NCRS

$$NCRS(\{(R_{i\{j\}}, SNR_{ij})\}) = \{(\gamma_i^l, R^l)\} \text{ where} \tag{30}$$

$$n_j \in J, \text{ and } \gamma_i^l \text{ is solution of} \tag{31}$$

$$\text{Maximize} \sum_l \gamma_i^l \delta_i^l \text{ where } \sum_l \gamma_i^l = 1, \tag{32}$$

$$\delta_i^l = R^l (1 + \sum_{k \neq m, n_k \in J} q"{}_{iJ}^{k}) / Z_{iJ}^m, \tag{33}$$

$$n_m \text{ is a direct target and is cts-node,} \tag{34}$$

$$min_j(R_{i\{j\}}) \leq R^l \leq max_s(R_{i\{s\}}), \tag{35}$$

$$n_s \in J \text{ and } n_s \text{ is a direct target} \tag{36}$$

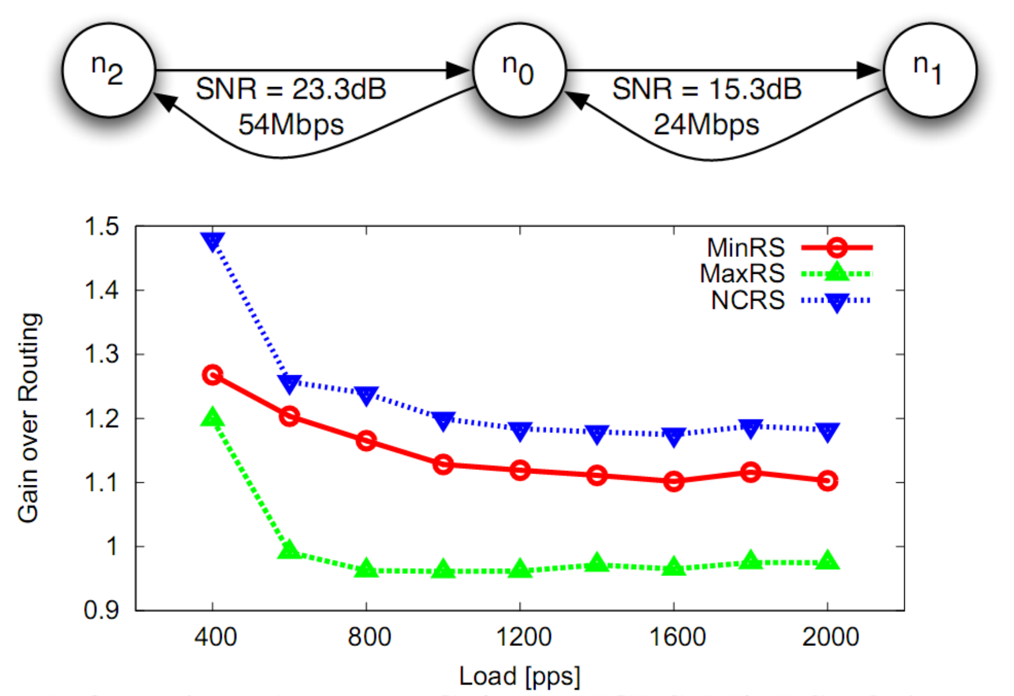
Baseline Schemes

$$MinRS(\{(R_{i\{j\}}, SNR_{ij})\}) = min_j(R_{i\{j\}}) \text{ , } n_j \in J$$

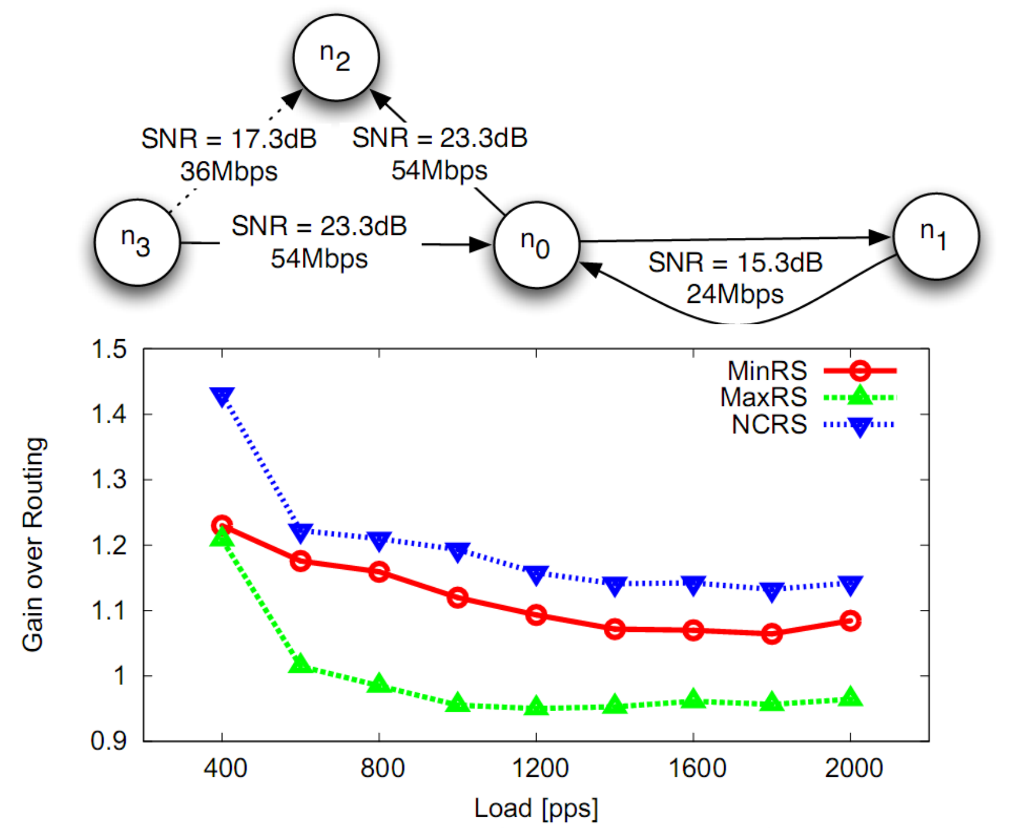
$$MaxRS(\{(R_{i\{j\}}, SNR_{ij})\}) = max_j(R_{i\{j\}}) \text{ where}$$

$$n_j \in J \text{ and is a direct target}$$

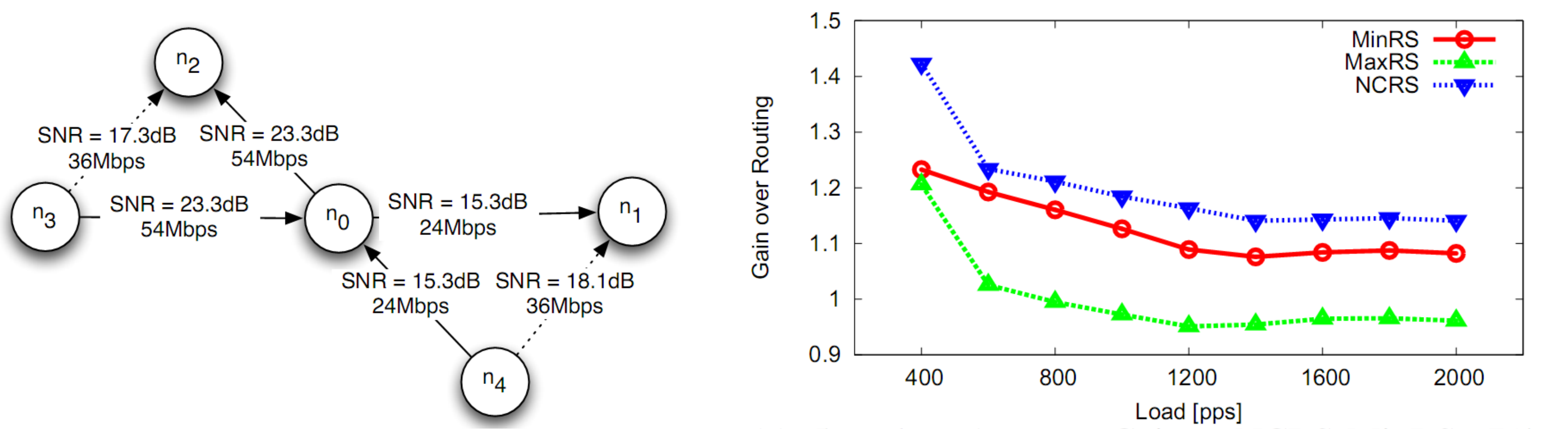
Small Scenarios



(a) 3 nodes, Average Gain - NCRS-MinRS: 9%, NCRS-MaxRS: 24%



(b) 4 nodes, Average Gain - NCRS-MinRS: 8%, NCRS-MaxRS: 20%



(c) 5 nodes, Average Gain - NCRS-MinRS: 7%, NCRS-MaxRS: 20%

3 Nodes – Varying Combinations

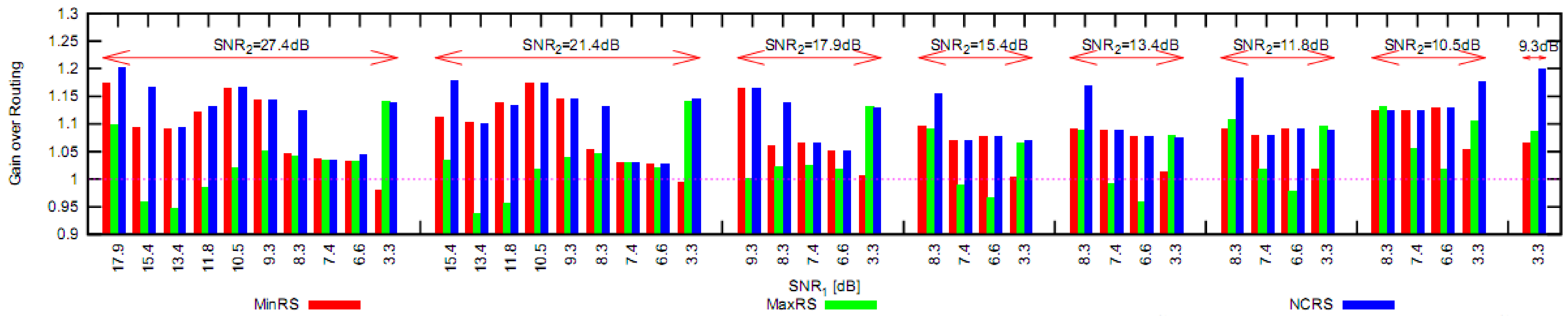
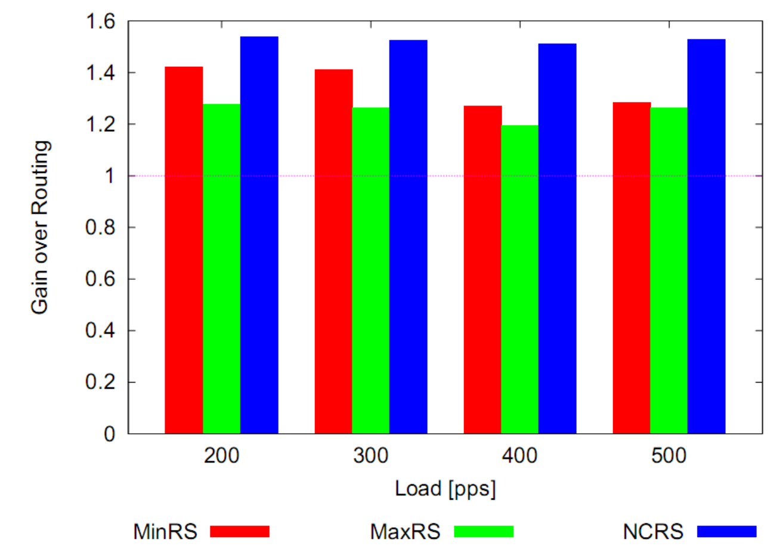


Fig. 5. Gain over routing for packets delivered to all hops for 3-node scenarios with varying SNR combinations - SNR_1 = SNR on $n_0 \rightarrow n_1$, and SNR_2 = SNR on $n_0 \rightarrow n_2$, Load = 1500pps, Maximum Gain - NCRS-MinRS: 16%, NCRS-MaxRS: 21%

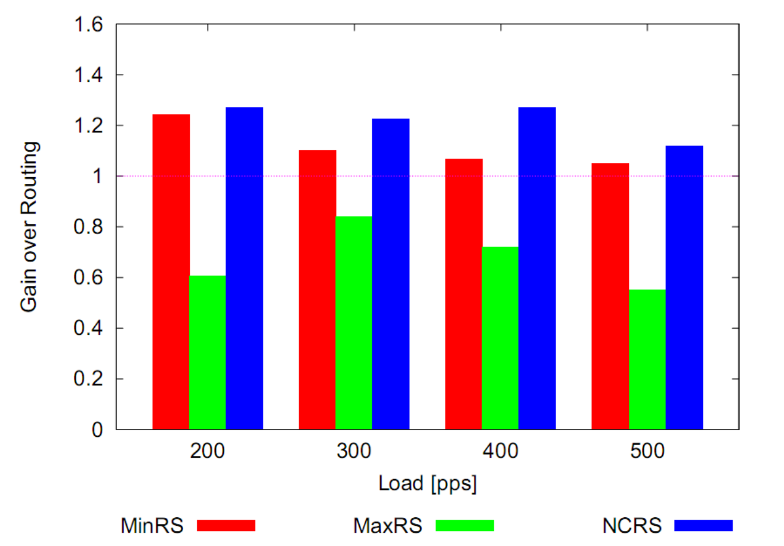
Conclusions

- ❑NCRS is widely applicable
- ❑NCRS is suited for a wide range of scenarios whereas MinRS and MaxRS face performance degradation under specific conditions
- ❑NCRS brings up to 24% and 55% gain over MinRS and MaxRS, respectively, for large scenarios

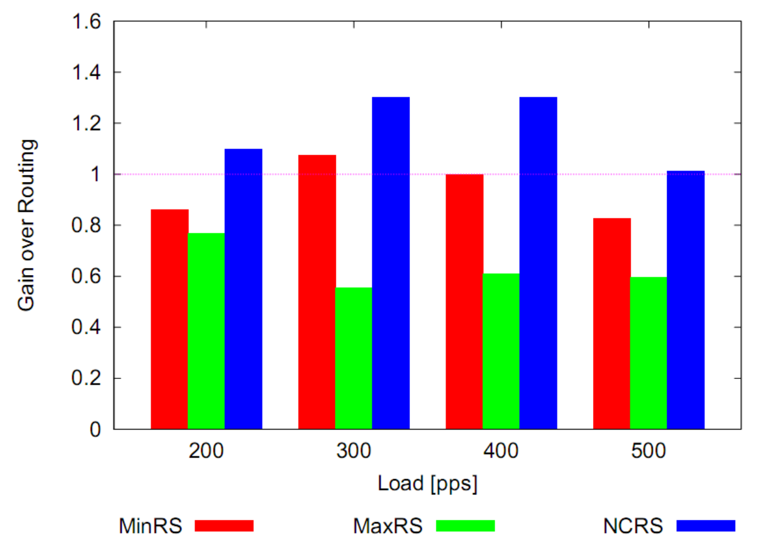
Large Scenarios



(a) 4 flows, Average Gain - NCRS-MinRS: 18%, NCRS-MaxRS: 28%



(b) 8 flows, Average Gain - NCRS-MinRS: 11%, NCRS-MaxRS: 54%



(c) 12 flows, Average Gain - NCRS-MinRS: 24%, NCRS-MaxRS: 55%

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