Using Relay Balance and AQM Schemes to Improve Performance in Multi-hop Wireless Networks

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Outline

- Introduction
- Multi-hop transmission and delay performance
- Relay balance and flush-front schemes
- Simulation results
- Conclusions

Introduction

- Multi-hop wireless communication is an important mechanism to extend the network coverage.
- In such networks, for nodes that are relaying multiple flows, ***congestion can easily occur*** and ***the queue length quickly grows***.
  - which experience significant degradation of both throughput and delay performance.

Introduction

- As queuing time has a considerable impact on delay, ***distributed queue management schemes*** potentially can improve delay performance.
- Other mechanisms that can be used to avoid the congestion in networks include ***rate control*** and ***admission control*** [5], ***scheduling algorithms*** [3, 6], or other approaches such as ***network deformation*** [7].
- Numerous studies focus on how to improve throughput, however, proposals to reduce delay are scarce.

Introduction

- Active queue management (AQM) schemes [8] control the queue by appropriately dropping packets before queues overflow in order to avoid congestion.
- The packets to be discarded can be packets arriving at the tail of the queue (drop-tail) or packets at the head of the queue (drop-front).

Introduction

- Among drop-tail schemes, RED [9] and its variances are known as efficient schemes in wired networks (e.g. Internet).
- In wireless networks, these schemes need some modifications [4, 10] in order to adapt with the dynamic wireless links.
- With these modifications, throughput of TCP traffic and fairness can be improved; however delay performance is not addressed.

Introduction

- However, there are few studies of drop-front schemes in the dynamic environment of **multi-hop wireless networks**.
- In this paper, combining the ***relay balance scheme*** [15] with a drop-front AQM scheme, called **flush-front**, which reduces the end-to-end delay, while maintaining network throughput.

Delay in a multi-hop wireless network

- In multi-hop communication, end-to-end delay of a packet is the sum (at every hop) of the packet processing times;
  - the time the packet spends in the queue (at network layer)
  - the time the packet waits to be scheduled to send over the channel (at MAC layer)
  - the propagation times

Delay in a multi-hop wireless network

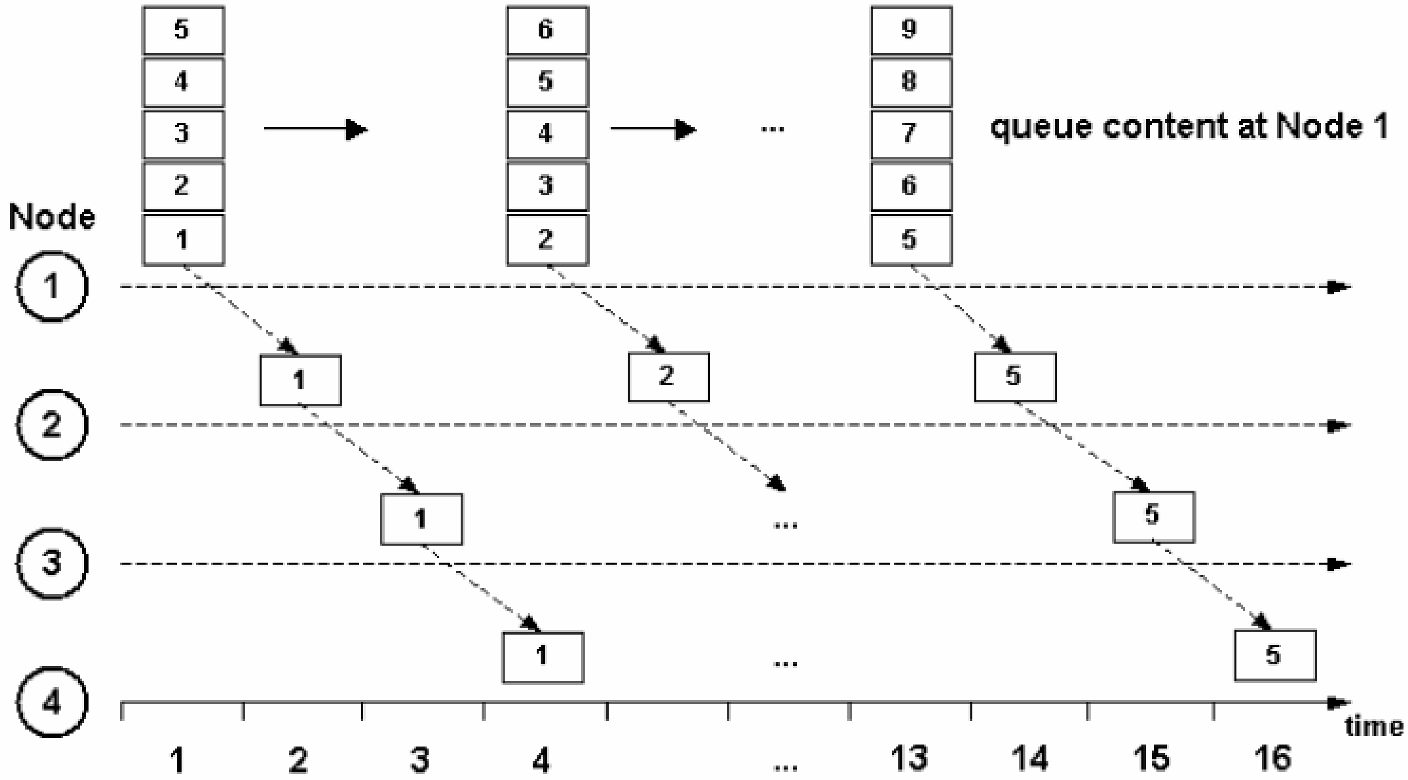

Fig. 1 Delay of packets over multi-hop wireless transmission

Delay in a multi-hop wireless network

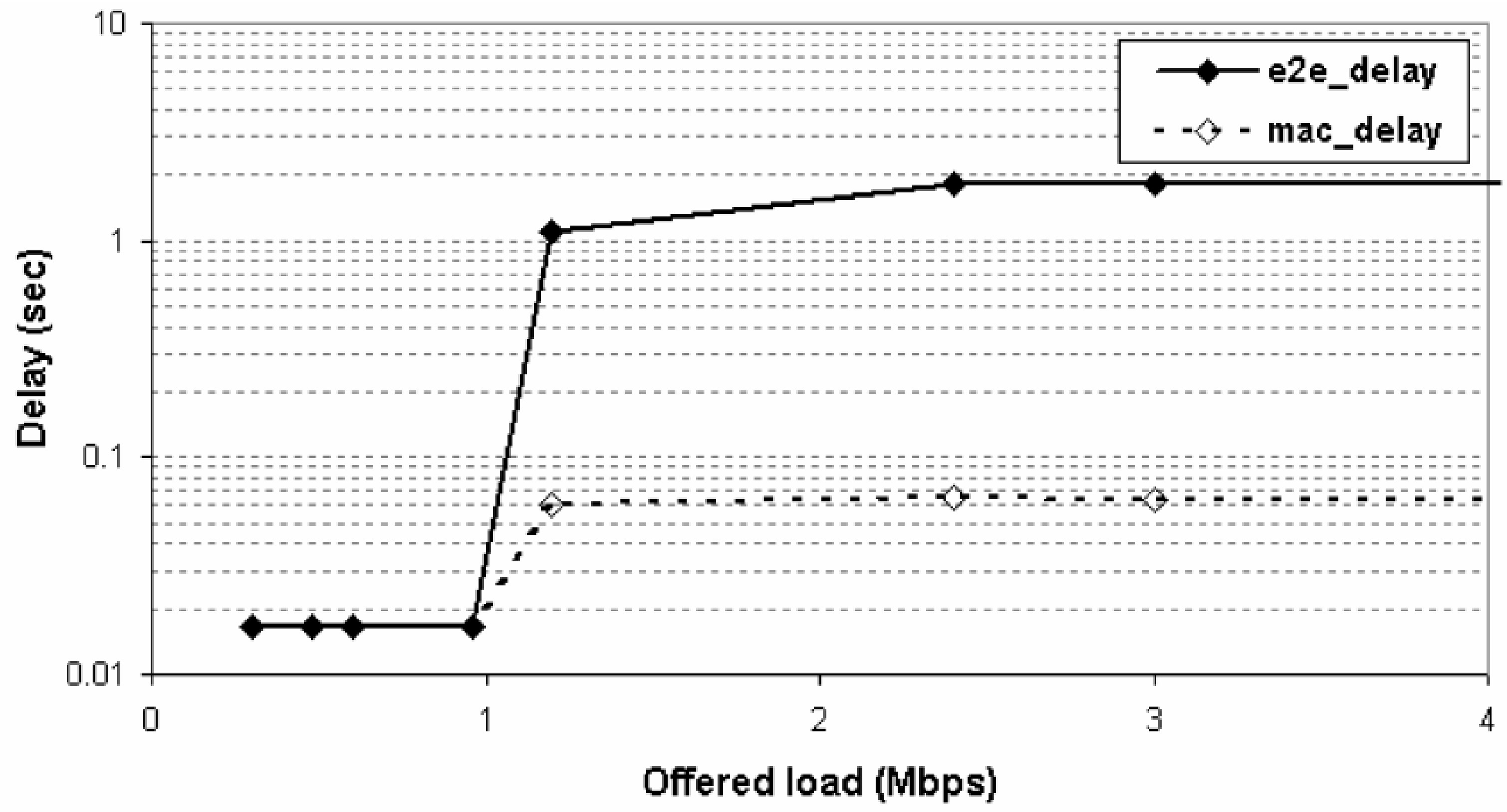

Fig. 2 MAC delay is a small portion of end-to-end delay

Drop-tail versus drop-front AQM

- In order to improve the delay performance of wireless transmission over multi-hop, it is necessary to reduce both the **MAC delay** and **the queuing delay at network layer**.
- The queuing delay is the dominant portion of end-to-end delay, therefore this paper focuses on the impact of AQM schemes on reducing queuing delay.
    - Note that the improvement of MAC protocol is still important because queuing delay also depends on MAC delay.

Drop-tail versus drop-front AQM

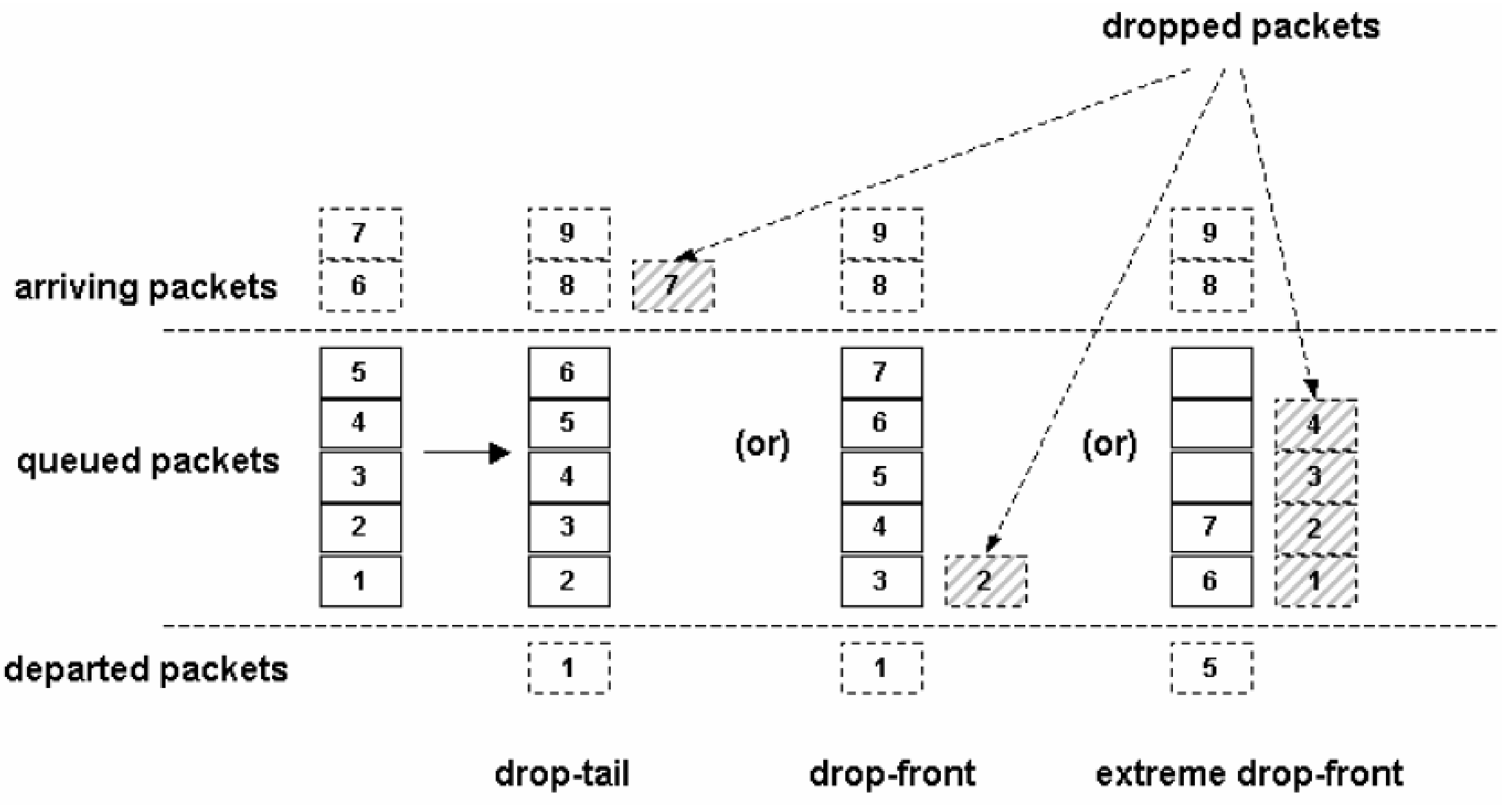

Fig. 3 AQM strategies

Drop-tail versus drop-front AQM

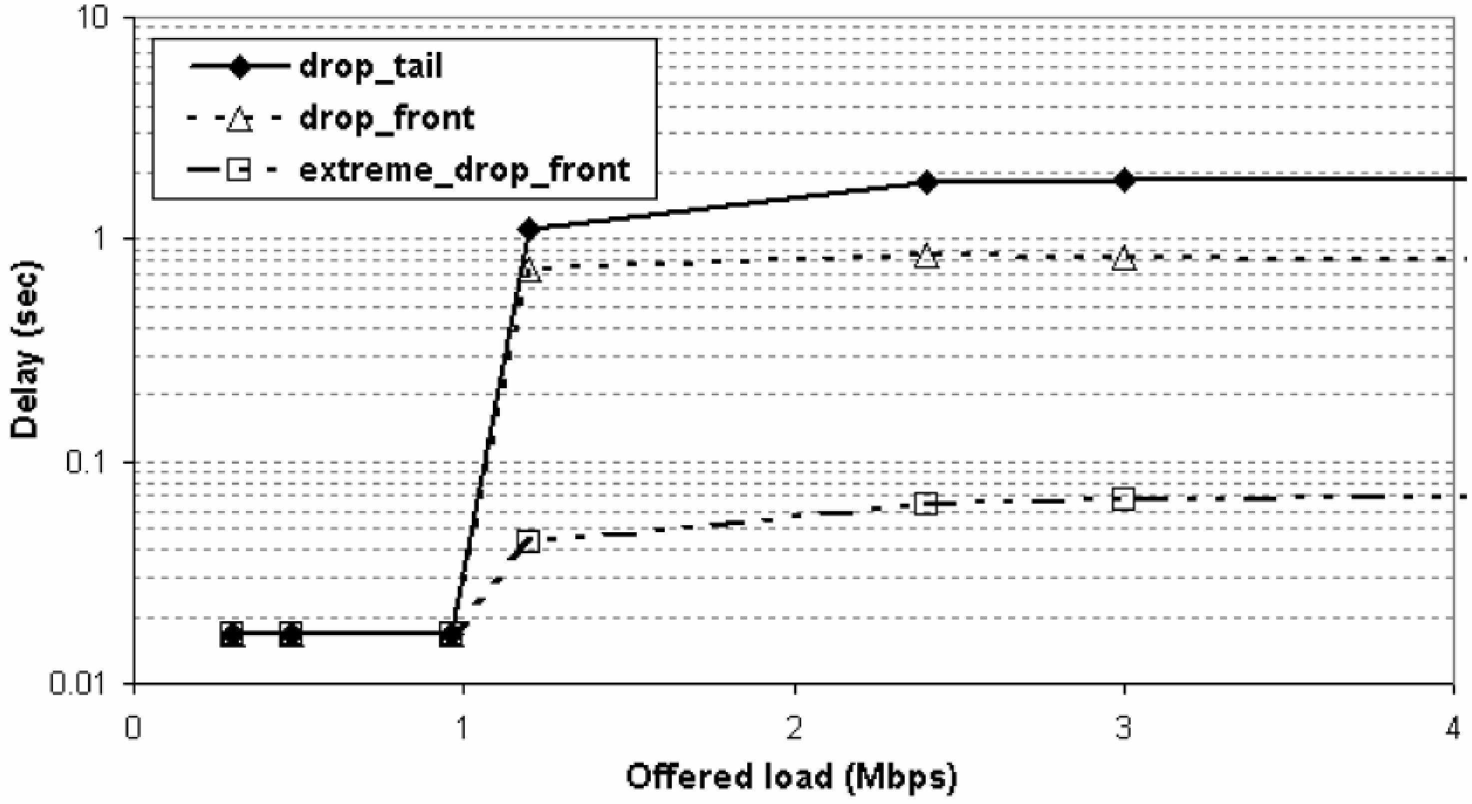

Fig. 4 End-to-end delay performance of different AQM strategies

Drop-tail versus drop-front AQM

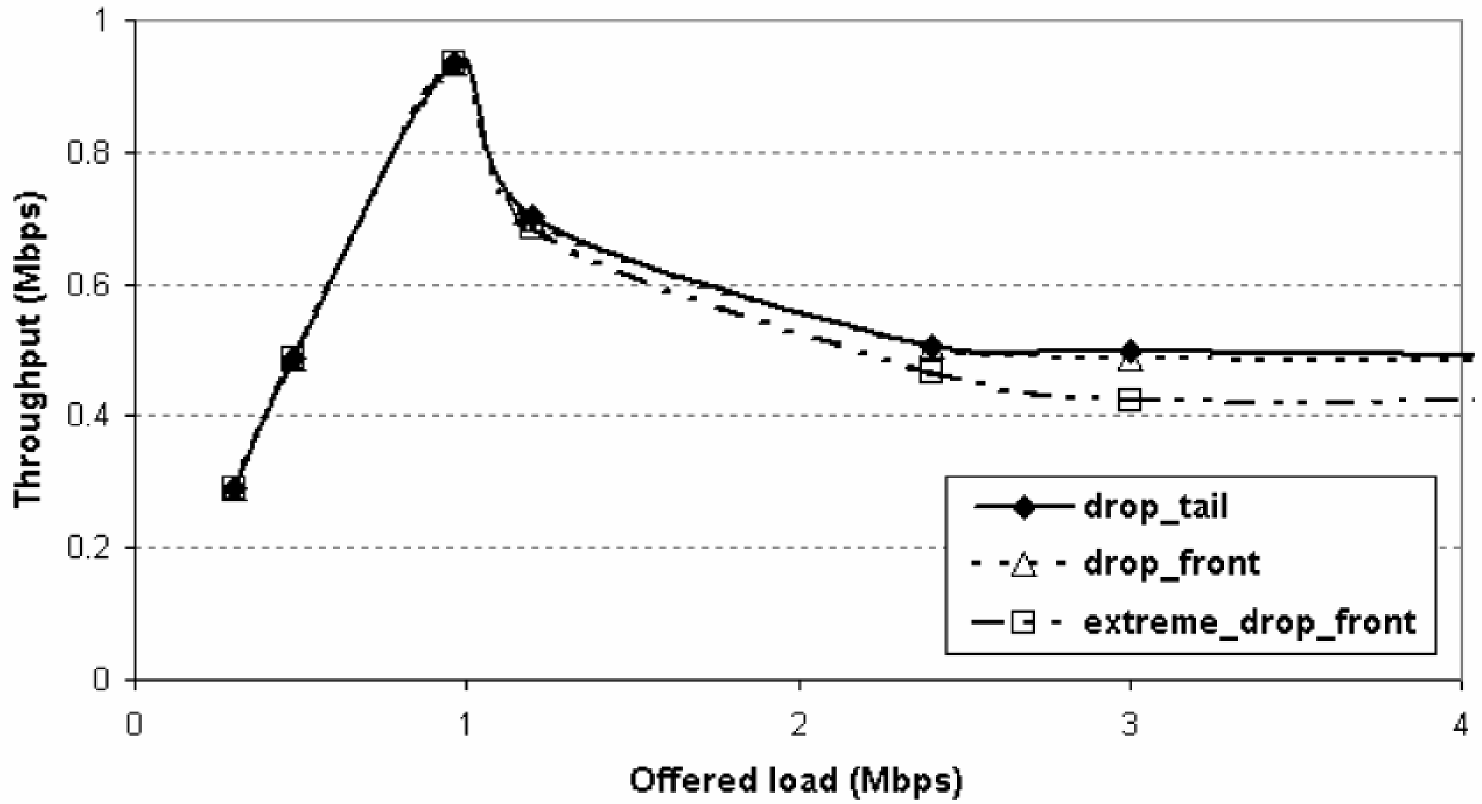

Fig. 5 Throughput performance of different AQM strategies

Drop-tail versus drop-front AQM

- The analysis also suggests that an AQM scheme should satisfy two paradoxical requirements of having a **small queue** to lower delay and **keeping queue big enough** to maintain throughput.

Relay balance and flush-front schemes

Relay balance scheme

- The idea behind this scheme is based on the observation that a pure relay (an intermediate) node is inefficient in relaying if it forwards less data than it receives
- This suggests that by maintaining the balance between its incoming and outgoing traffic, a relay node can improve its performance towards optimal efficiency.

Relay balance scheme

- The balance is maintained if ***the queue length is small*** or ***the difference between receiving and forwarding rates is small***.
- In the cases where the queue length or the difference of rates exceeds certain thresholds, the relay stop receiving packets in order to favor forwarding activities until the balance condition is restored

Design of the proposed flush-front scheme

- The challenge in designing an AQM scheme is to balance between the requirements of a small queue to lower the delay while keeping a sufficient large queue to maintain throughput.

Design of the proposed flush-front scheme

- Flush-front scheme maintains three queue thresholds: *min_thresh*, *flush_thresh* and *max_thresh*.
- When packets arrive, flush-front follows the drop-front strategy
  - i.e. it allows packets to join the queue at the tail, if the queue is full (queue length exceeds *max_thresh*), head packets are dropped to make room for new packets.

Design of the proposed flush-front scheme

- The *flush_thresh* is computed as follows:

  flush_thresh = **max**(**min**(*D**Rs* , *max_thresh*), *min_thresh*)

  - where *D* is the expected queuing delay of a packet
    - Which depends on the requirements of applications.
  - *Rs* is the estimation of the average packet sending rate.

Design of the proposed flush-front scheme

- The main modification in flush-front scheme is the computing of ***a dynamic queue threshold of flush_thresh***, which is driven by the average packet sending rate, instead of keeping a fixed and small queue size.
- When there are more transmission opportunities (higher *Rs*), *flush_thresh* increases and allows more packets to be queued to maintain the throughput.
- When *Rs* is reduced, the number of packets in the queue is decreased to lower the delay.

Simulation results

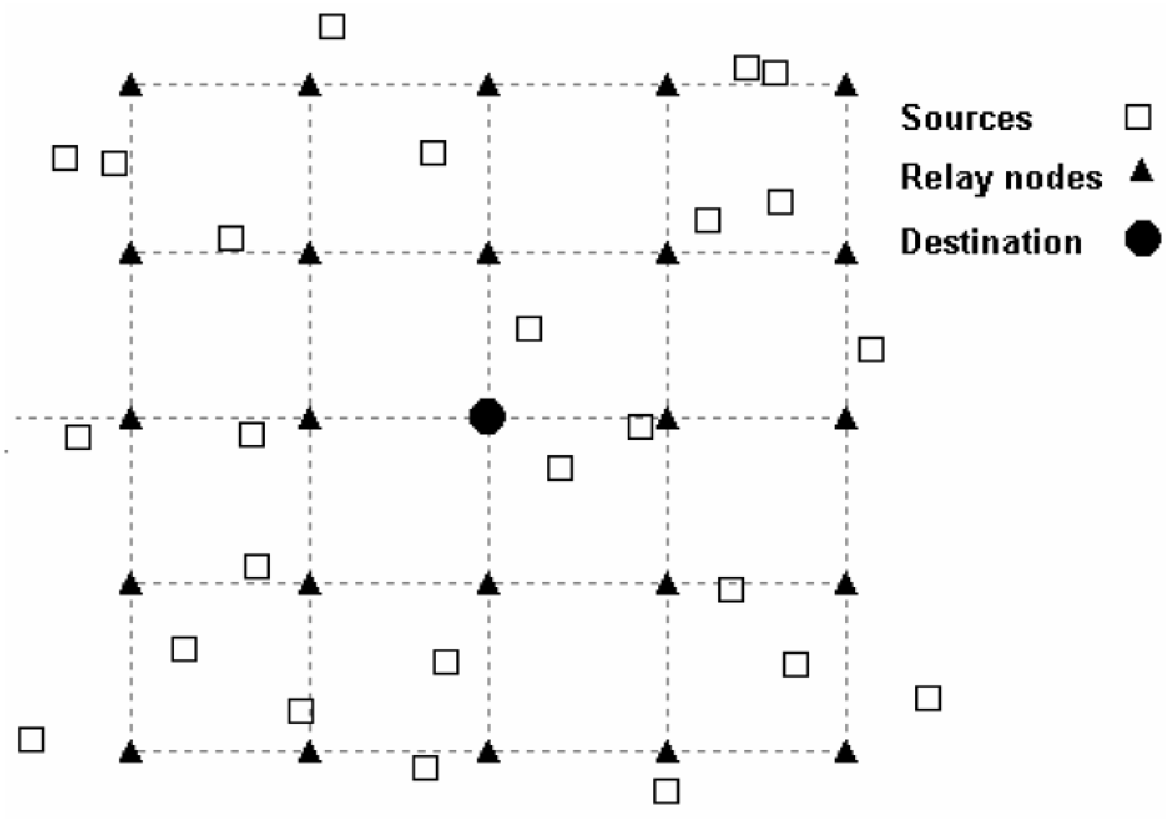

Fig. 6 A nodes placement scenario

Simulation results

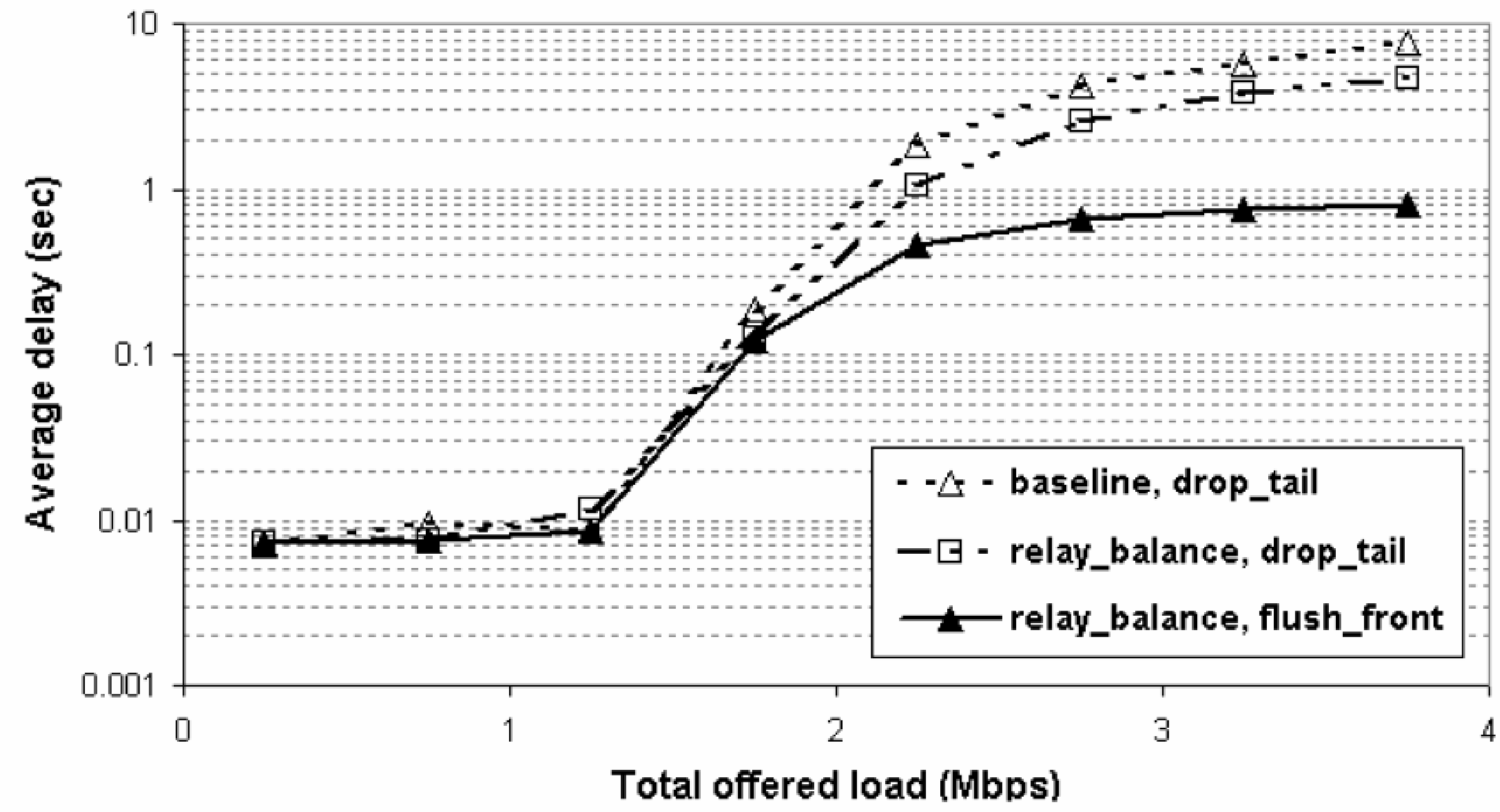

Fig. 7 Average end-to-end delay measured at the gateway

Simulation results

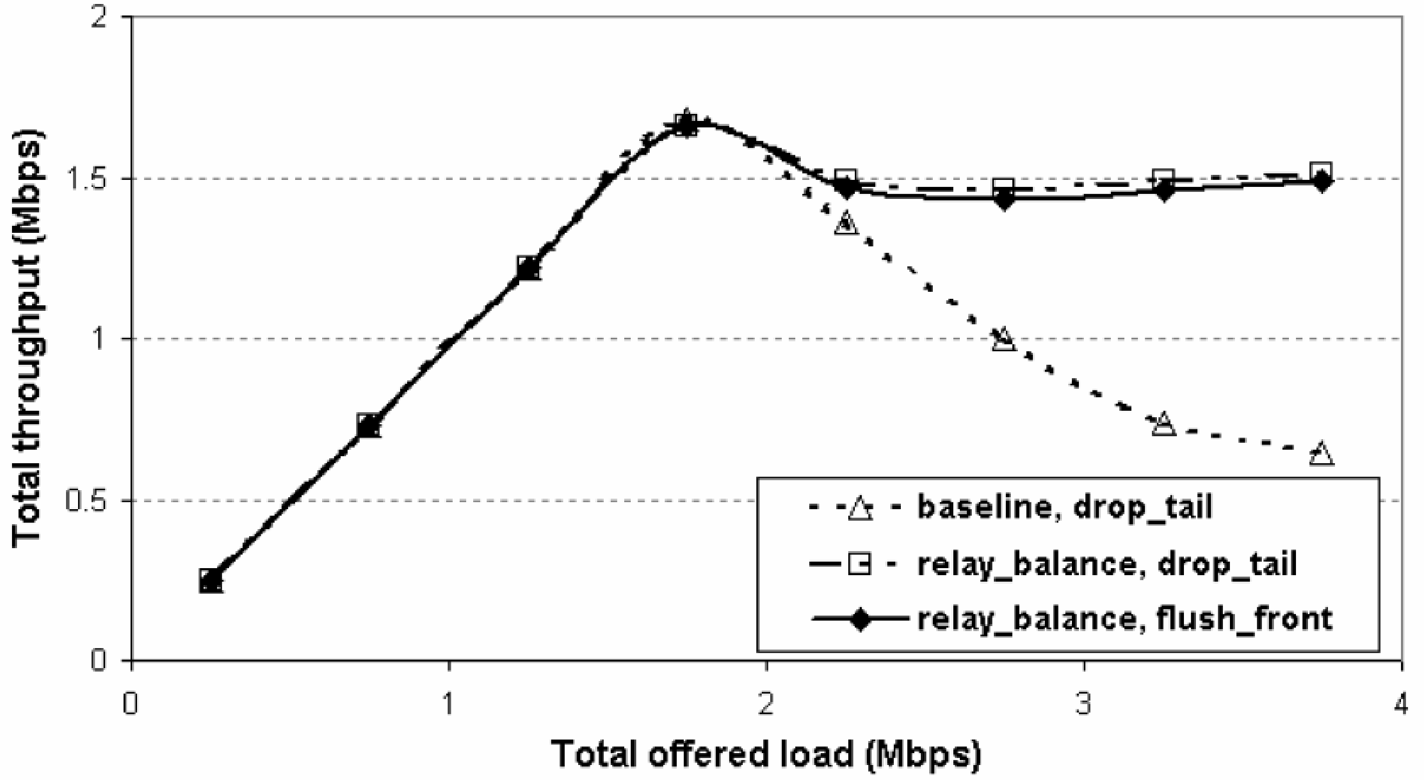

Fig. 8 Total throughput measured at the gateway

Simulation results

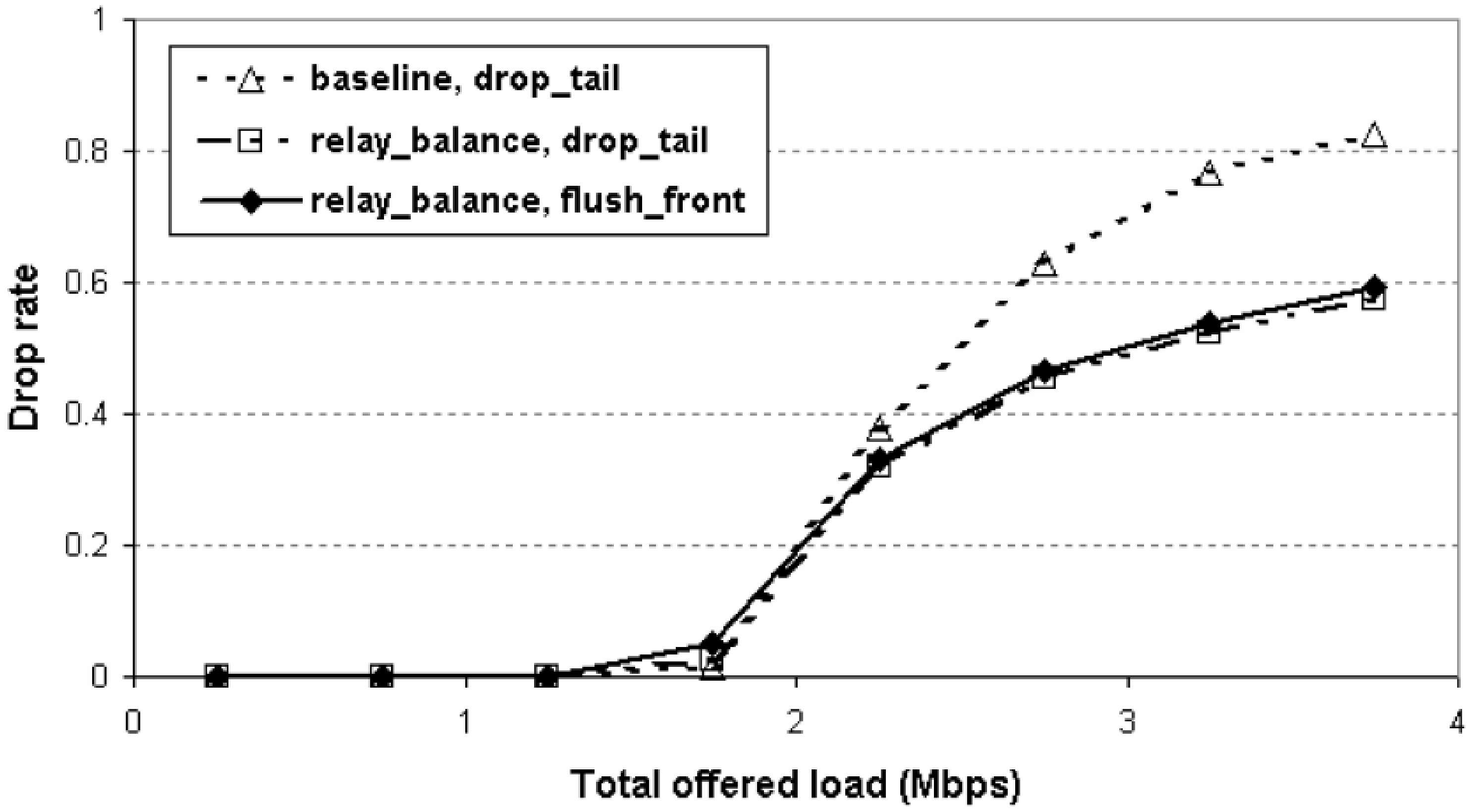

Fig. 9 Packet dropping rate

Conclusions

- In a multi-hop wireless environment, the excessively high delay in saturation conditions is not desirable for many applications.
- To reduce the delay, this paper replaces the conventional drop-tail scheme by flush-front scheme in conjunction with a relay balance scheme.
  - Flush-front scheme queues newer packets, shortens the queuing time of a packet, thus effectively reduces the delay.
  - Relay balance scheme would provide stable and high throughput performance.