# Comparative Study of Routing Metrics for Multi-Radio Multi-Channel Wireless Networks

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# Outline

- Introduction
- Related Works
- AETD : The Proposed Routing Metric
- Performance Evaluation
- Conclusion

# Introduction

- IEEE 802.11 system often suffers low channel utilization and poor system throughput.
- Recently, the multi-radio multi-channel network architecture has been recognized to improve performance.

- Challenges in multi-radio multi-channel network architecture:
  - channel assignment
  - channel utilization
  - high-throughput routing
- This paper focuses on routing problem.

# Related Works

- To find a better path:
  - hop-count routing metric (HOP)
  - cumulative expected transmission count (ETX) : link-quality factor
  - cumulative ETT (CETT) : transmission rate
  - WCETT : channel diversity

# Computing ETX

$$p = 1 - (1 - p_f) * (1 - p_r)$$

$$s(k) = p^{k-1} * (1 - p)$$

$$\mathrm{ETX} = \sum_{k=1}^{\infty} k * s(k) = \frac{1}{1 - p}$$

p: probability of transmission failure

pf: forward pr:reverse

S(k): probability of transmission successful with k times

# Computing ETT

- The authors define the ETT of a link as a “bandwidth-adjusted ETX”

$$\mathrm{ETT} = \mathrm{ETX} * \frac{S}{B}$$

S: packet size
B: bandwidth

# WCETT

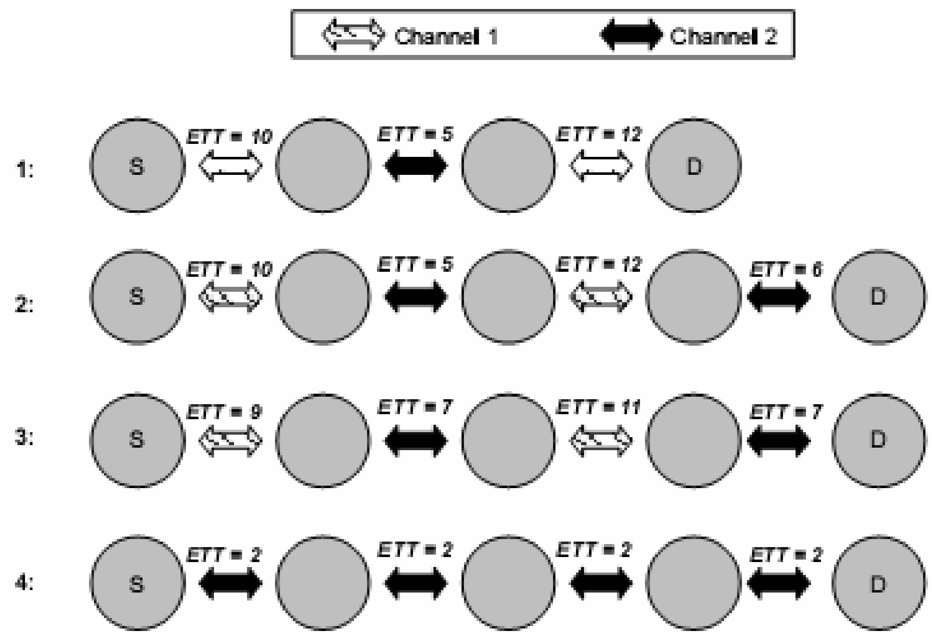
- Consider the impact of channel diversity

$$X_j = \sum_{\text{Hop i is on channel j}} \mathrm{ETT}_i \quad 1 \leq j \leq k$$

$$\mathrm{WCETT} = (1-\beta) * \sum_{i=1}^{n} \mathrm{ETT}_i + \beta * \max_{1 \leq j \leq k} X_j$$

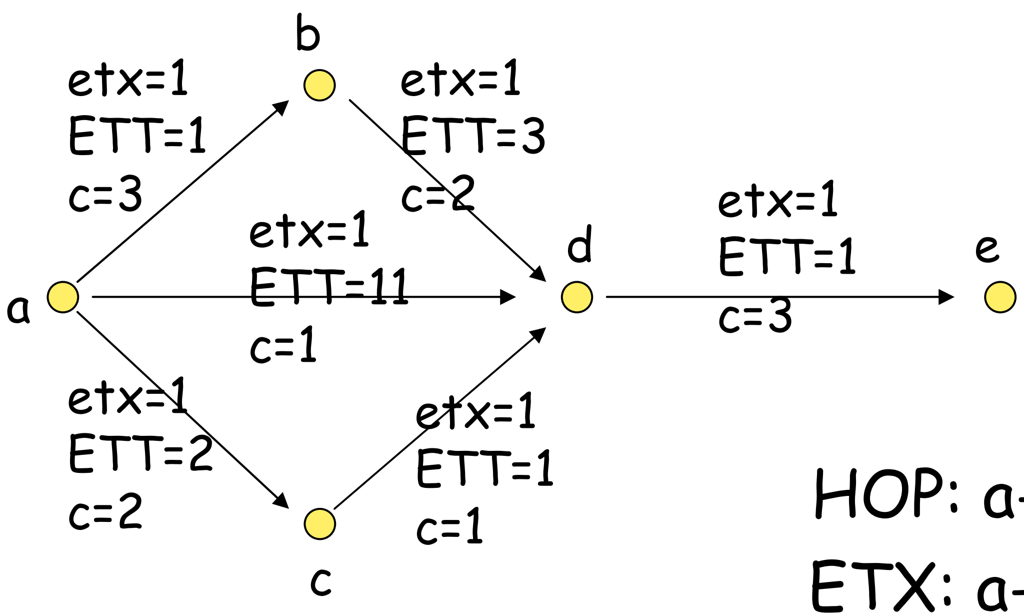
# WCETT (cont.)

- Impact of $\beta$




| Path | Sum | Max | WCETT ($\beta = 0.9$) | WCETT ($\beta = 0.1$) |
|---|---|---|---|---|
| 1 | 27 | 22 | 22.5 | 26.5 |
| 2 | 33 | 22 | 23.1 | 31.9 |
| 3 | 34 | 20 | 21.4 | 32.6 |
| 4 | 8 | 8 | 8 | 8 |

# Example




Source: a
Destination: e

HOP: a->d->e

ETX: a->d->e

CETT: a->c->d->e

WCETT: a->b->d->e

# The Proposed Routing Metric

- The authors bring up two new metrics:
  - ETD: Expected end-to-end transfer delay
  - EDJ: The lower bound of expected delay jitter

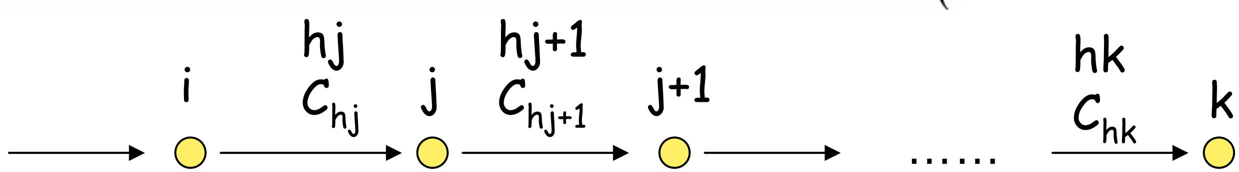
- The authors think an ideal route shall have a small ETD as well as a small EDJ.

# Computing ETD and EDJ

$$\mathrm{ETD}_r = \sum_{h_i \in \mathcal{H}_r} \mathrm{ETT}_{h_i}.$$

m: interference distance

$$\mathrm{EDJ}_{r(i)} = \begin{cases} \mathrm{ETT}_{h_k} & \text{if } i = k-1, \\ \mathrm{ETT}_{h_{i+1}} + \mathrm{EDJ}_{r(i+1)} & \\ \quad \text{if } \exists\, i+1 < j \leqslant \min\{i+m+1,\ k\} & \\ \quad \text{such that } C_{h_{i+1}} = C_{h_j}, & \\ \max\{\mathrm{ETT}_{h_{i+1}},\ \mathrm{EDJ}_{r(i+1)}\} & \text{else,} \end{cases} \quad (4$$

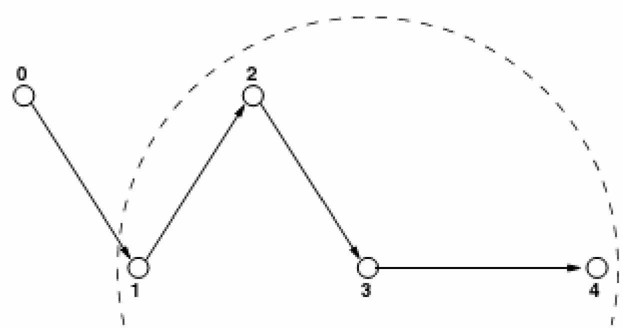


# AETD (adjusted expected transfer delay)

- Algorithm

$$\mathrm{AETD} = (1 - \alpha) \times \mathrm{ETD} + \alpha \times \mathrm{EDJ}$$

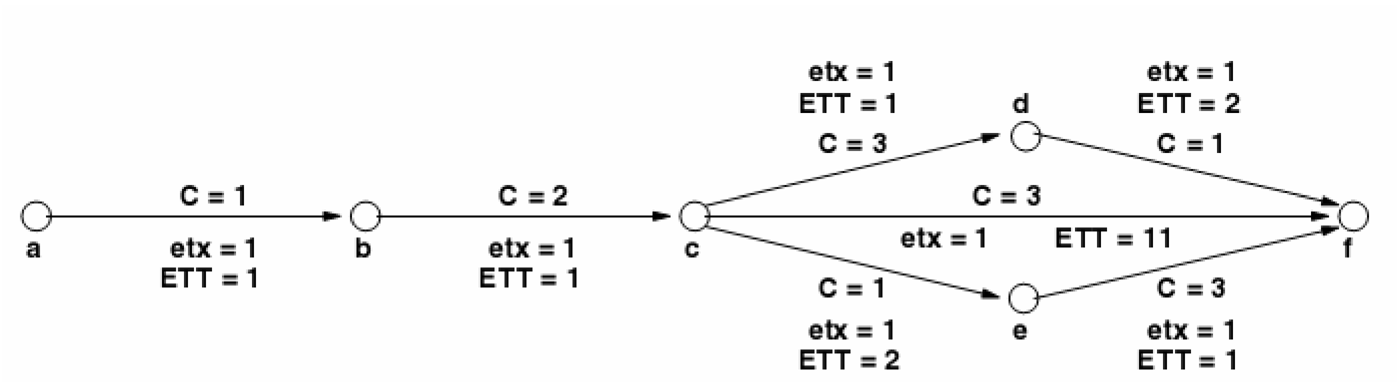
- Different from WCETT
  - consider the following circumstance




(b) a zigzag route

Fig. 1. Problem with the hop-distance-based interference model

# Example




| available routes | routing metrics | | | |
|---|---|---|---|---|
| | HOP | ETX | WCETT | AETD |
| [a-b-c-f] | 3 | 3 | $(1-\beta)\cdot 13+\beta\cdot 11$ | $(1-\alpha)\cdot 13+\alpha\cdot 11$ |
| [a-b-c-d-f] | 4 | 4 | $(1-\beta)\cdot 5+\beta\cdot 3$ | $(1-\alpha)\cdot 5+\alpha\cdot 2$ |
| [a-b-c-e-f] | 4 | 4 | $(1-\beta)\cdot 5+\beta\cdot 3$ | $(1-\alpha)\cdot 5+\alpha\cdot 3$ |
| route selection | [a-b-c-f] | [a-b-c-f] | [a-b-c-d-f] or [a-b-c-e-f] | [a-b-c-d-f] |

# Performance Evaluation

- Using QualNet simulator
- Impact of $\alpha$
  - 2km*2km
  - 200nodes/km2

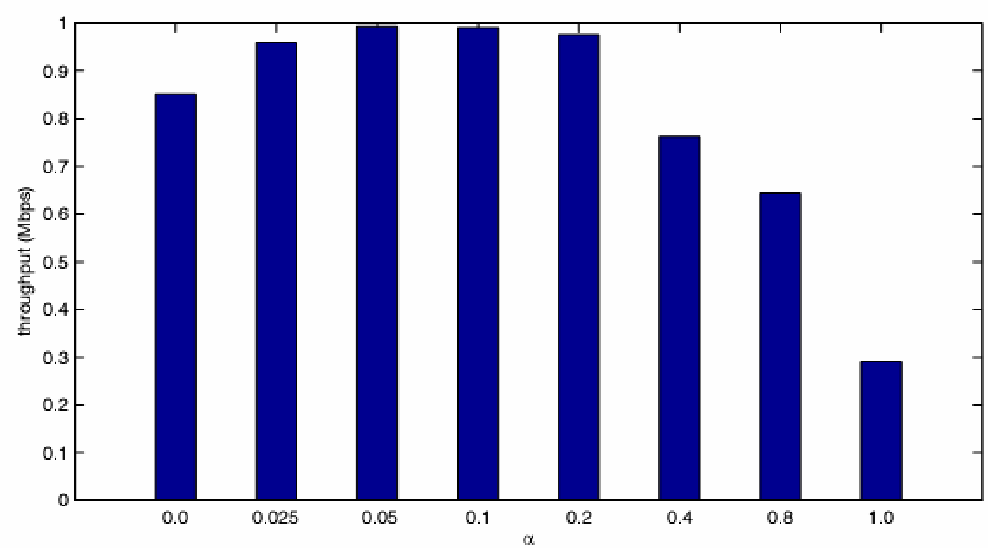



Fig. 4. Comparison of AETD with various $\alpha$

# Network Density & Network Size

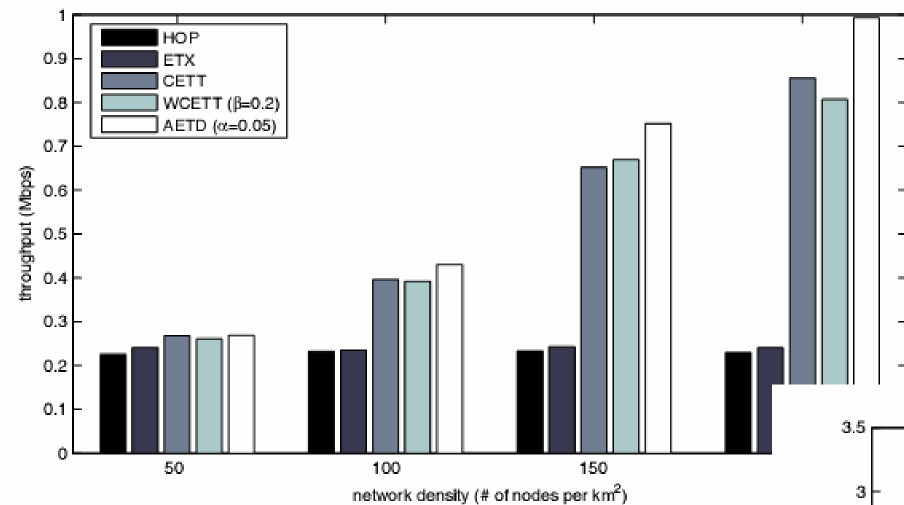



Fig. 5. Throughput comparison with various node c

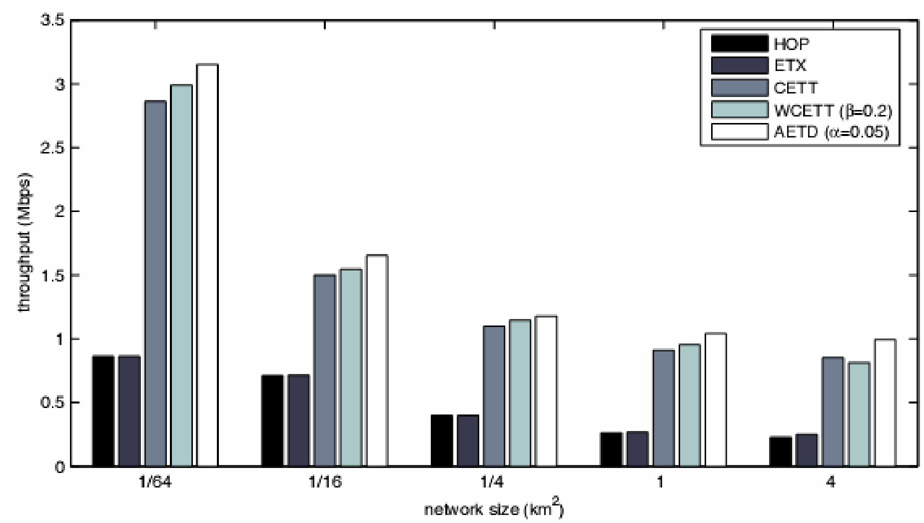



Fig. 6. Throughput comparison with various network sizes

# Number of Available Channels

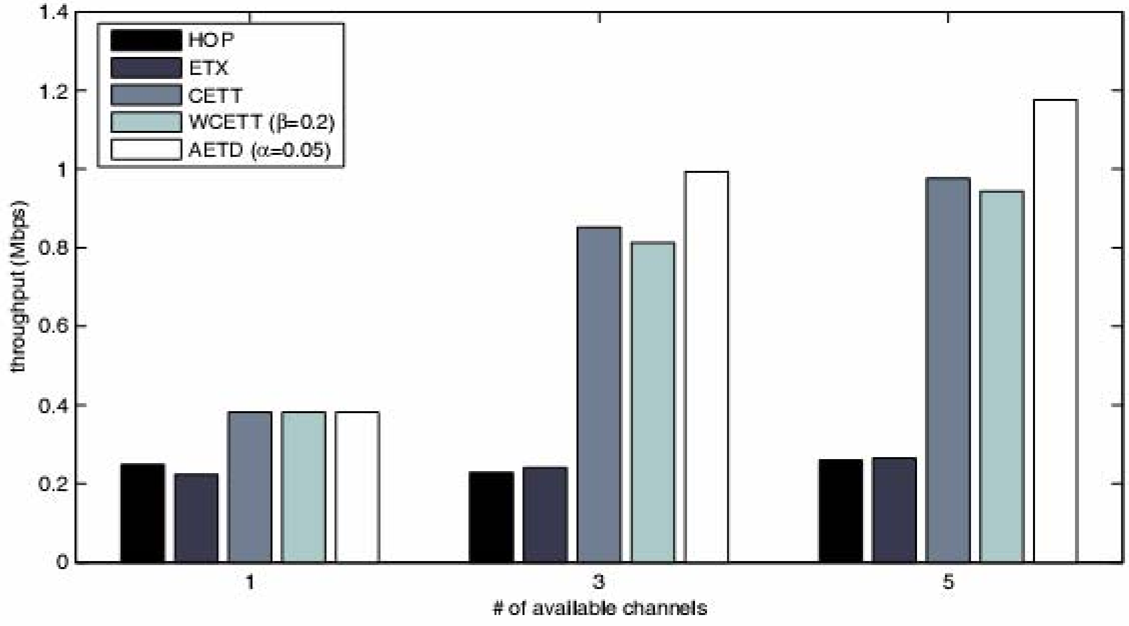



Fig. 7. Throughput comparison with various numbers of available channels

# Conclusion

- A new AETD routing metric is proposed.
- The simulation results suggest the EDJ is a good indicator of channel-diversity level.
- The authors compare these methods finally.