Diagnosing Wireless Packet Losses in 802.11: Collision or Weak Signal ?

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University of Wisconsin Madison

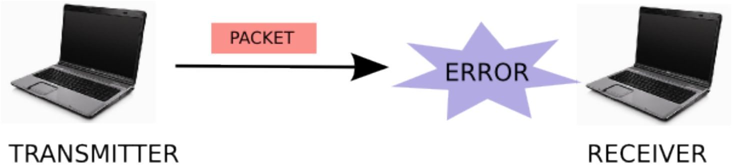
INFOCOM 2008

Consider a wireless link:

TRANSMITTER

RECEIVER

Consider a wireless link:



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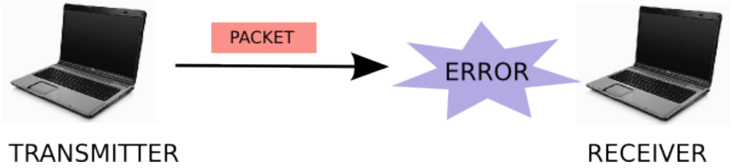
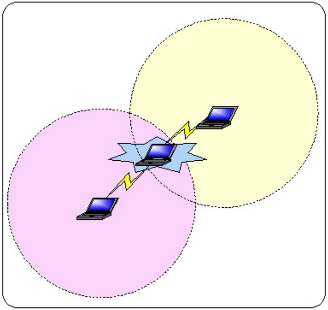


Q. What caused the packet loss?

Wireless Errors

Wireless Errors

Collision



Wireless Errors

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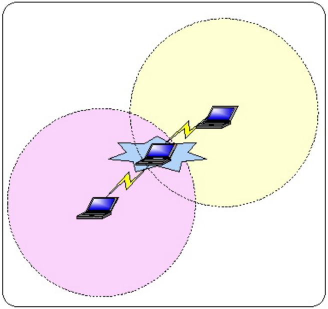
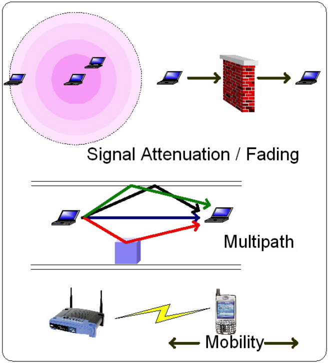
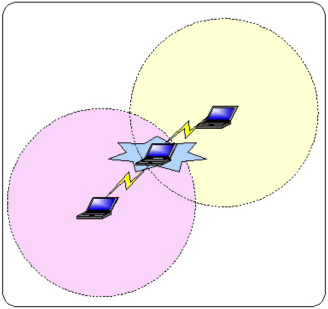


Weak Signal

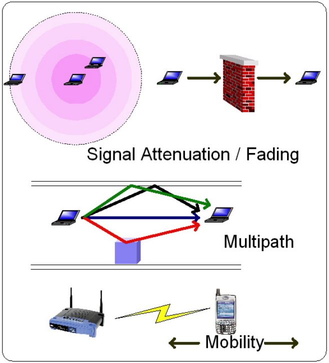


Wireless Errors

Collision



Weak Signal



Q. Can we discern between these two?

Collision vs. Weak Signal

Q. Why is it important to distinguish between errors?

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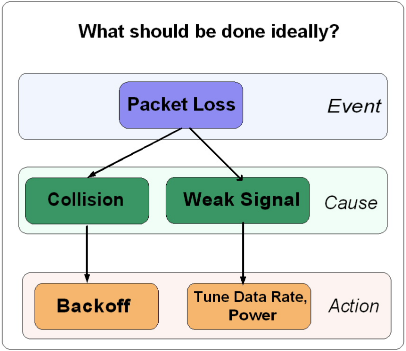

Collision vs. Weak Signal

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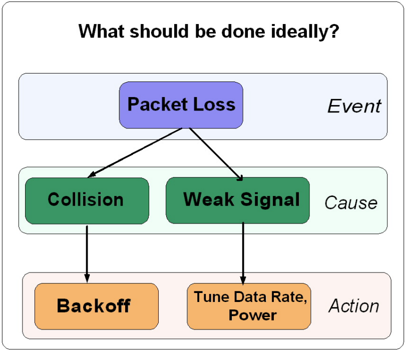

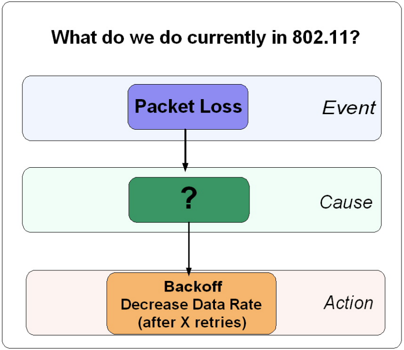

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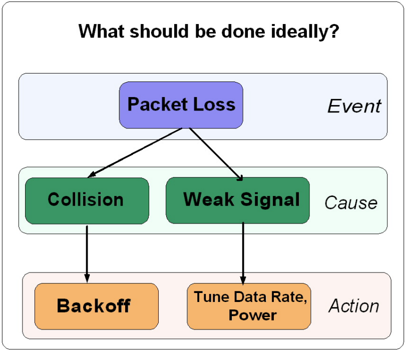

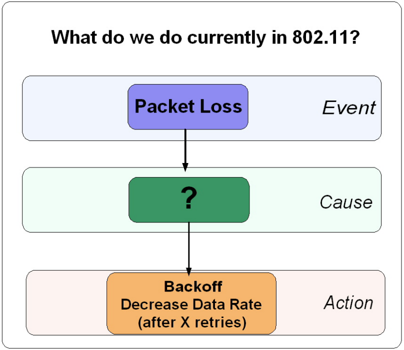

Throughput
Energy ↓

Collision vs. Weak Signal

Inferring the cause of error

- 'Collision Detection' is hard!
- Given an error packet, can we conduct a post-mortem?

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Example

1 0 0 1 1 1 0 1 0 1 1 0 1	TX Packet

Collision vs. Weak Signal

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Example

1 0 0 1 1 1 0 1 0 1 1 0 1	TX Packet
1 1 0 1 1 0 1 1 0 0 1 1 1	RX Packet

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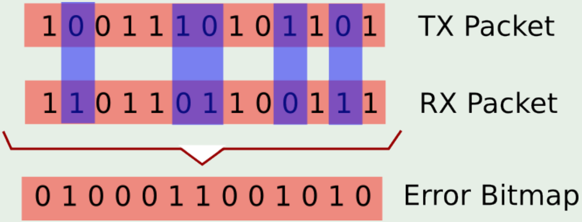
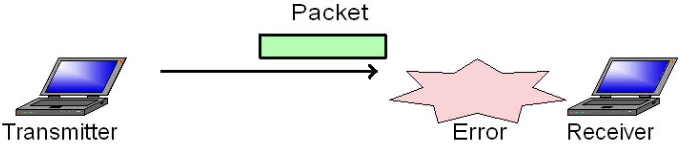


A Simple Approach



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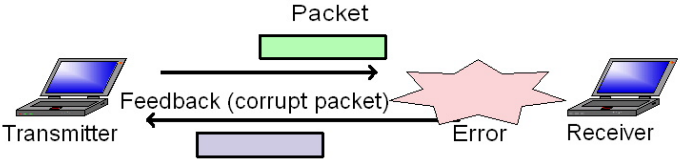

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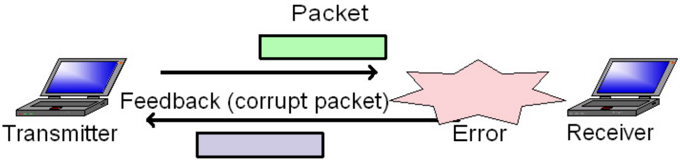

Metrics used to discern the cause:

- Received signal strength (RSS)
- Bit error rate (BER)
- Error rate per symbol (EPS)
- Symbol error rate (SER)
- Symbol error burst length (S-Score)

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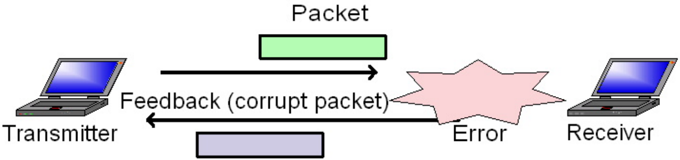

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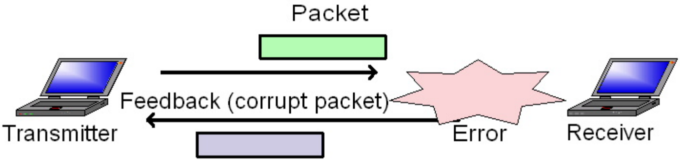

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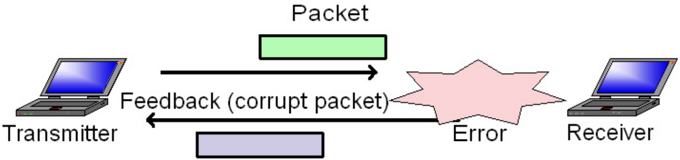

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Metrics : Intuition

Bit Error Rate (BER)

- Percentage of total bits in error

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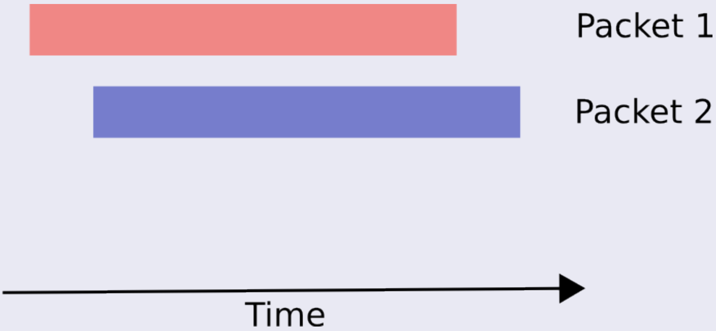

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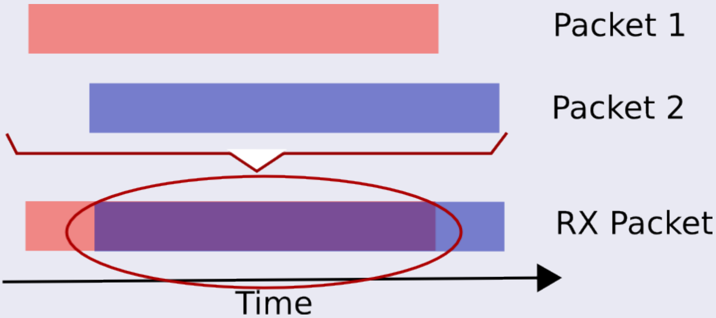

Metrics : Intuition

Bit Error Rate (BER)

- Percentage of total bits in error (Higher in collision?)

Received Signal Strength (RSS)

- RSS $\sim$ (S+I/n)

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Bit Error Rate (BER)

- Percentage of total bits in error (Higher in collision?)

Received Signal Strength (RSS)

- RSS $\sim$ (S+I/n) (Lower in weak signal?)

Metrics : Intuition

Symbol Error Rate (SER)

- Percentage of symbols which are in error

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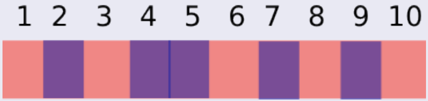

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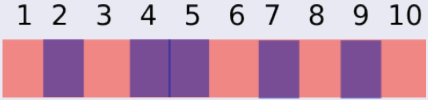

$$\text{SER} = 5/10 = 0.5$$

Metrics : Intuition

Symbol Error Rate (SER)

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- Percentage of bits in error averaged over the symbols which are in error

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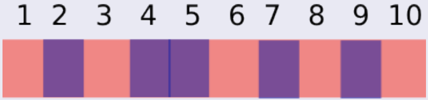

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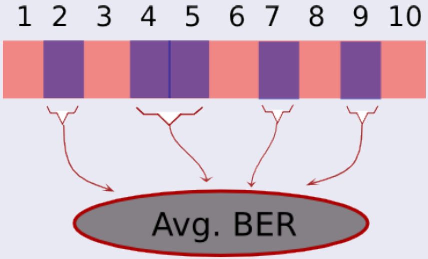

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Error Per Symbol (EPS)

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S-Score

- Measure of number of consecutive symbols in error

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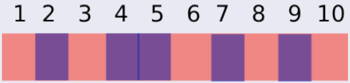

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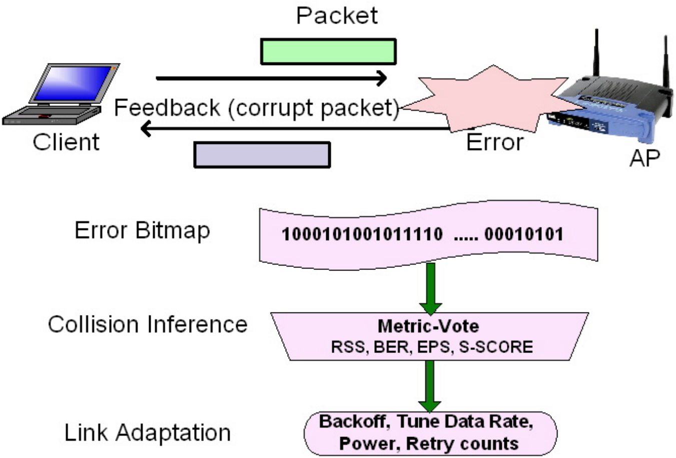
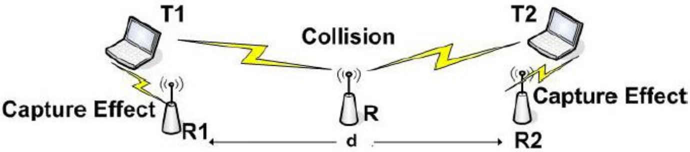
$$\text{S-Score} = \sum_{i=1}^{n} |B_i|^2$$

Summary of Approach



Weak Signal

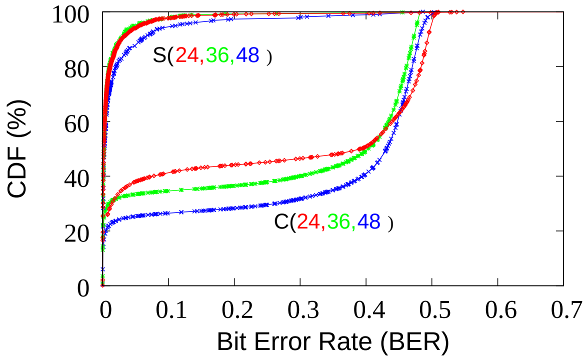
- Environment free of other 802.11 transmissions
- Enabled reception of packets in error
- Client mobility induced errors due to dynamic channel conditions



Collisions

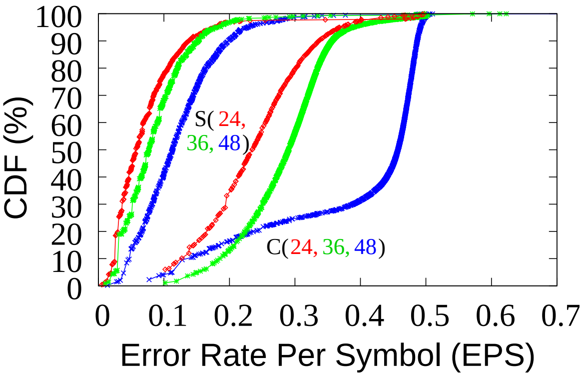
- Disabled backoffs, enabled reception of packets in error
- Packet logs at the receivers are synchronized using common packets
- Collisions are identified using overlap in packet transmission times

Empirical Results : BER



- 98% of weak signal packets have a BER of 12% or less
- 26% of collision packets have BER of 12% or less
- Cutoff value of 12% BER: Detects 74% of collisions with 2% false positives

Empirical Results : EPS



- 98% of weak signal packets have an EPS of 22% or less
- 30% of collision packets have the same EPS of 22% or less.

A Metric-Vote Scheme

Metric-Vote

- Output a collision if any of the metrics vote for a collision

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Performance

Table: Accuracy for Collision/Weak Signal

	BER	EPS	S-Score	Metric-Vote
Collision	55.0	52.4	44.1	59.7
Weak Signal	99.43	97.80	98.74	97.40

- Accuracy: % of weak signal (or collision) packets which are correctly identified

Some Observations

Why is the accuracy low for collision packets?

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- **Strong Capture Effect**

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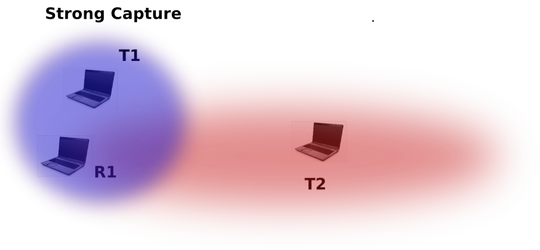
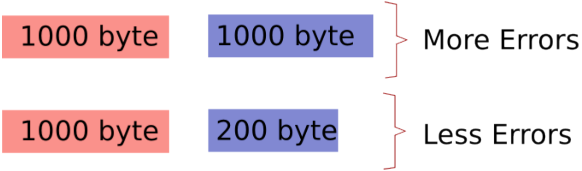
- **Strong Capture Effect**



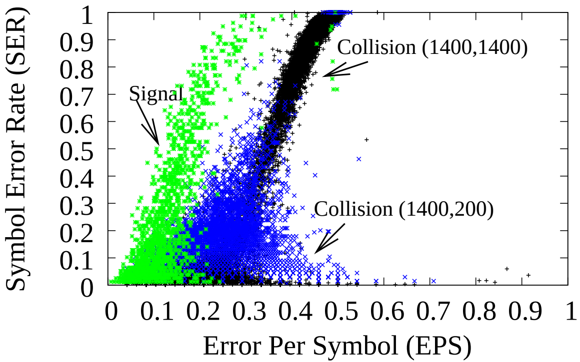
Some Observations

Why is the accuracy low for collision packets?

- **Strong Capture Effect**
- **Colliding Packet Size**



A Joint Metric : SER-EPS

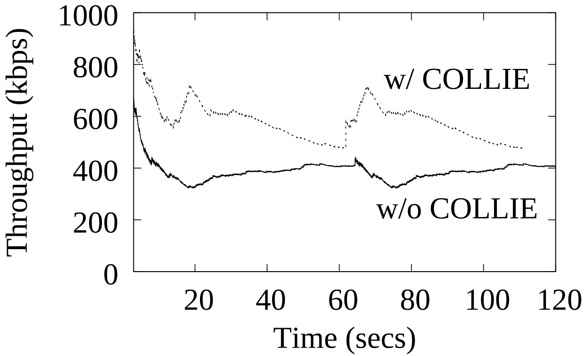


Reference Implementation

- **Platforms**: Linux based laptop, Netgear SPH101 VoWiFi phone
- **COLLision Inferencing Engine (COLLIE)**
  - AP relays the error packet back to the client
  - Client performs collision inferencing
- COLLIE based Link Adaptation
  - Enhanced Auto Rate Fallback to make it collision-aware

Mobile Scenario

- Mobile Client, Presence of other traffic

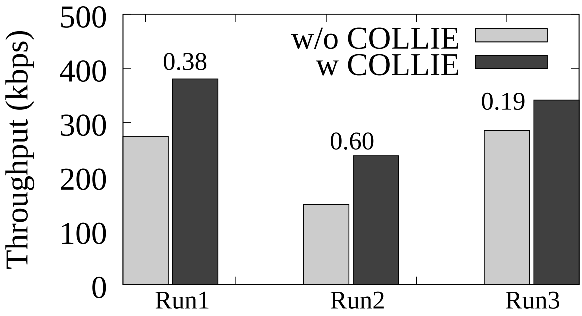


- **Throughput improvement $\sim$ 30%**

Results (2)

Collision Scenario

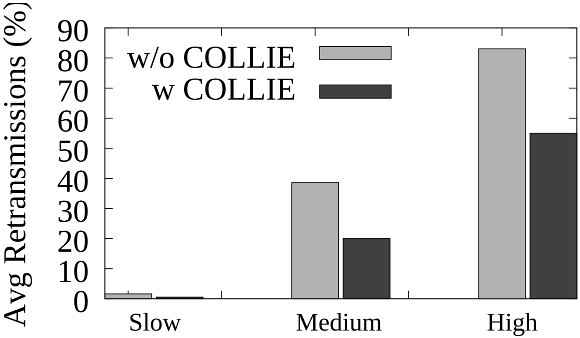
- Static client, Presence of additional collision sources



- **Throughput improvement as high as 60%**

Voice call emulation

- Netgear SPH-101 VoWiFi phone using TI chipset and proprietary rate adaptation algorithm



- **Reduction in wasted retransmissions $\sim$ 40%**

Summary and Future Work

Summary

- We addressed the fundamental question of **'what caused a packet to be in error – collision or weak signal?'**
- Distinguishing between errors lead to improvement in throughput, energy efficiency

Future Work

- Design better metrics
- Design a low overhead protocol
- Study the impact of non-802.11 interference sources
- Enhance/design link adaptation mechanisms

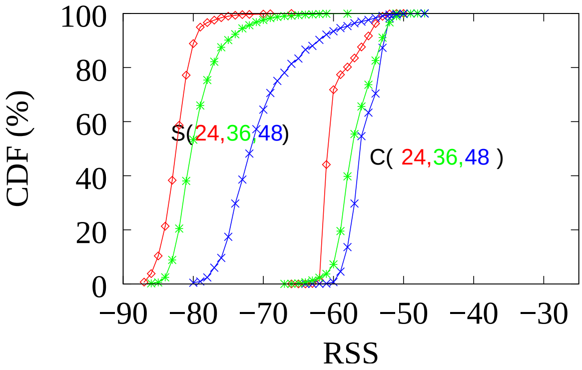
Questions?

Backup slides

Empirical Results : Other Metrics

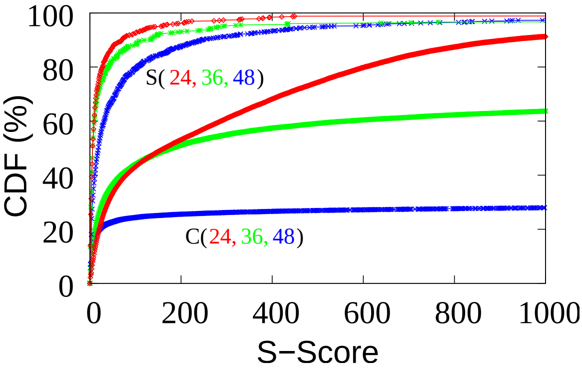
- **S-Score**
  - Cutoff value of 500: 98% of signal packets and 26% of collision packets
- **RSS**
  - High variation
  - Delivery probability is a function of $S/(I+n)$ instead of $(S+I)/n$, receiver sensitivity

Empirical Results : RSS



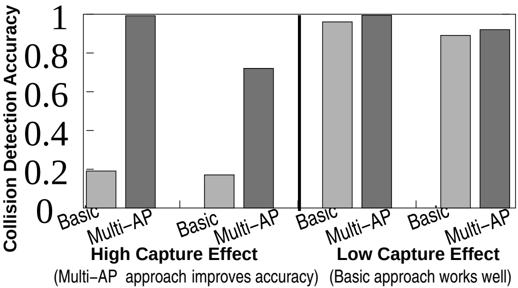
- 98% of packets in error due to weak signal have an RSS of about -73 dBm or less
- 10% of packets suffering collision have RSS of -73 dBm or less

Empirical Results : S-Score



- 98% of the weak signal packets have an S-Score of 500 or less
- 26% collision packets have an S-Score of 500 or less

Multi-AP Assistance



- APs are synchronized (using opportunistic common packet receptions)
- Information about packet reception is aggregated at the COLLIE server