1. Introduction
- Packet losses in WiFi networks can occur due to poor channel conditions, collisions, or hidden nodes.
- Determining the cause of packet loss is important for the optimization of various components of WiFi protocols (e.g., backoff protocol, rate adaptation).
- Lack of loss differentiation can severely degrade throughput.
- Prior loss differentiation schemes either require customized hardware support, protocol changes or incur large overhead.
- We propose BLMon, a low overhead loss differentiation scheme for high speed WiFi (802.11n) networks, which leverages differences in loss patterns and frame retries to determine the cause of loss.
- BLMon achieves high accuracy without requiring any changes protocol changes or customized hardware support.

2. Background
- In 802.11n, senders can transmit multiple packets on every channel access.
- The aggregate of multiple packets is called A-MPDU (Aggregate MAC Protocol Data Unit).
- For every successful A-MPDU transmission, a block ACK is sent by the receiver.
- A block ACK has a bitmap, that indicates the reception status of each MPDU.
- Losses within A-MPDUs reveal significantly distinct patterns.

3. Experimental Study
- **NOISE ANALYSIS**
  - One sender-receiver pair
  - Mostly isolated losses
  - Less than 5 consecutive losses in ~80% A-MPDUs on link with ~30% PER
  - Retries are rare

- **COLLISION ANALYSIS**
  - Two senders, one receiver
  - 99.9% of A-MPDUs in collision had all MPDUs corrupted
  - Retry once only due to random backoff

- **HIDDEN NODE ANALYSIS**
  - Two senders, one receiver
  - Senders either experience isolated losses or large consecutive losses.
  - Multiple number of retries

4. Pattern in A-MPDU Analysis
- **(a) NL**
- **(b) CL**
- **(c) HCL**

Fig (above): White bars indicate lost A-MPDUs, green bars indicate successful A-MPDUs, blue bars indicate A-MPDUs that are retried once and red bars indicate A-MPDUs retried more than once.

5. Metrics
- **Burst Isolation Index (BII):** $BII = L_e / L$, where $L$ is the number of MPDUs received in error and $L_e$ is the number of “01” and “10” transitions in the Block ACK bitmap.
- **A-MPDU Retries (ARET):** Number of times A-MPDUs is retried.
- **Packet Error Rate (PER):** Ratio of MPDUs received in error to total number of MPDUs.

6. BLMon Experimental Results
- Evaluation of each individual metric on real traces.
- Traces contain losses due to noise, collisions and hidden nodes.
- Evaluation with BLMon using Detection Accuracy (DA) and False Positive (FP) rate.
- BLMon outperforms all individual metrics both in terms of DA and FP.
- Average DA ($\geq 96.7\%$) and FP ($\leq 0.97\%$) when link PER is $33\%$.
- When link PER is $66\%$ FP is high under RCL due to increase in bursty losses.

7. Related Work
- **Sofrate (Vatukuru et al., ACM SIGCOMM 2009):** uses BER estimate from PHY layer, requires customized hardware.
- **COLLIE (Rayancha et al., IEEE INFOCOM 2008):** uses error-patterns in PHY layer symbol, incurs overhead due to packet relay by the receiver for pattern analysis.
- Other schemes involve using RTS/CTS or PIFS; a non standard inter frame spacing for 802.11 DCF.

8. Key Contributions
- We conduct extensive experiments to highlight the difference between loss patterns and A-MPDU retries under different kinds of losses.
- We propose metrics for capturing the differences in patterns.
- We design BLMon, which uses these metrics to accurately differentiate between losses.

9. Future Work
- History based metrics to further improve BLMon performance.
- Evaluation of BLMon under mobile scenarios.
- Evaluation of BLMon’s performance when used by rate adaptation algorithms.
- Evaluation of BLMon’s performance when used by the exponential backoff algorithm.