WiFi-Nano: Reclaiming WiFi Efficiency through 800 ns Slots

Eugenio Magistretti † Krishna Kant Chintalapudi *
Božidar Radunović # Ramachandran Ramjee *

† Rice University * Microsoft Research India
# Microsoft Research Cambridge
Problem Overview

- **802.11 data-rates** have increased from 1 Mbps to 1 Gbps
- *Throughput performance* has not seen a commensurate increase
Contribution

WiFi-Nano increases 802.11 throughput up to 100%
Why Throughput $\ll$ Data-rate?

**54 Mbps**

- **Medium Access**: 101.5µs
- **Preamble**: 20µs
- **Data**: 224µs
- **ACK**: 44µs

Total: 405.5µs

**300 Mbps**

- **Medium Access**: 101.5µs
- **Preamble**: 32µs
- **Data**: 40µs
- **ACK**: 36µs

Total: 225.5µs

**600 Mbps**

- **Medium Access**: 101.5µs
- **Preamble**: 40µs
- **Data**: 20µs
- **ACK**: 44µs

Total: 221.5µs
Why Throughput $<<$ Data-rate?

54 Mbps

- Overhead $\approx 45\%$

300 Mbps

- Overhead $\approx 82\%$

600 Mbps

- Overhead $\approx 91\%$

802.11 overhead does not scale with data-rate
Communications Overhead
Cannot be removed!

Medium Access 101.5µs
Preamble 40µs
Data 20µs
Preamble+ACK 44µs

Preambles 40%
ACK 2%
Slot Duration 42%
SIFS 16%

Overhead Components

Motivation
Motivation

Overhead Components

Multiple Links Case (30)

- Preambles 34%
- ACK 2%
- SIFS 14%
- Slot Duration 23%
- Collisions 27%
Objective

- Reduce slot duration
  - and reduce the occurrence of collisions
  - … while preserving fairness
- Remove SIFS
Challenge: Slot Duration

- 802.11a/n slot duration of 9 µs is close to the minimum feasible

Key assumption:
Preamble detection and transmission are serial
Speculative Preambles

Preamble detection and transmission occur in parallel

Clear Channel Assessment may take multiple slots

The slot time can be reduced to a round-trip propagation delay

Slot Time (800 ns)
1. As soon as the backoff expires, a node transmits its preamble.

2. CCA: A node transmitting a preamble continues to attempt to detect incoming preambles.

3. A node aborts its transmission if it detects a preceding preamble.

Medium Access time decreases from 101.5 μs to 7.6 μs.
## WiFi-Nano Design

### Objectives
- Slot Time Duration
- Collisions
- Fairness
- SIFS

### Techniques
- Speculative Preambles
- Probabilistic Collision Resolution
- Counter Roll-back
- Minimum Slot Size
- Speculative ACKs
Implementation

- Detect preambles and their starting time under interference

Lattice Correlator

- Simultaneously transmit and detect preambles

Analog Self-Interference Canceller

- Interference may require longer preambles
Results

- Experiments
  - Reliability of Preamble Detection
  - Efficiency Gain and Analysis
  - Fairness

Lyrtech

Qualnet
Preamble Detection

Can nodes reliably detect preambles despite self-interference?

Slightly longer preambles permit to maintain reliability.
Efficiency

Efficiency $f(\text{data rate, #nodes})$

WiFi-Nano increases the throughput up to 100%
Efficiency

Efficiency $f(\text{data rate, slot time})$

WiFi-Nano increases the throughput up to 100%
How to Achieve More?

Frame Aggregation

- Works only for **single-link** bulk downloads
- Practically difficult to achieve
  - Small packets (TPC ACKs)
  - Short flows (HTTP)
  - Delay sensitive applications (TPC, VoIP)
Frame Aggregation

- Practically difficult to achieve
- Related work reports 18 kB as average aggregation

At 18 kB, WiFi-Nano gains 25% over 802.11 at 600 Mbps
Summary

802.11 overhead can be > 90%

- WiFi-Nano permits to
  - Reduce the **slot time to 800 ns**
  - Reduce the occurrence of **collisions to nearly 0**
  - **Remove SIFS**

WiFi-Nano increases 802.11 throughput up to 100%
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Q&A

Eugenio Magistretti †
Božidar Radunović #

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