

28th Jan SampleRate: bit rate adaptation in 802.11 wireless networks

Today MRD: exploiting radio link diversity with multiple access points

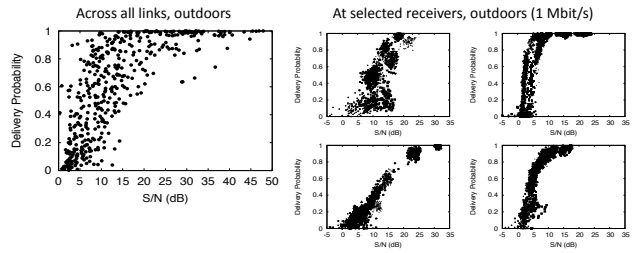
Monday ExOR: opportunistic routing in wireless mesh networks

SampleWidth: channel width adaptation

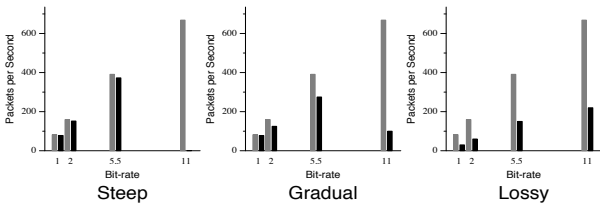
3rd Feb Interference cancellation in 802.11/Zigbee

4th Feb The Viterbi algorithm

SNR not a good measure?



Link classification



| Network | Total | Steep | Gradual | Lossy | Other |
|-----------------|-------|-------|---------|-------|-------|
| Indoor 802.11a | 100 | 26 | 41 | 22 | 0 |
| Indoor 802.11g | 108 | 16 | 86 | 21 | 0 |
| Indoor 802.11b | 168 | 98 | 144 | 24 | 0 |
| Outdoor 802.11b | 36 | 5 | 23 | 13 | 0 |

ARF

Algorithm

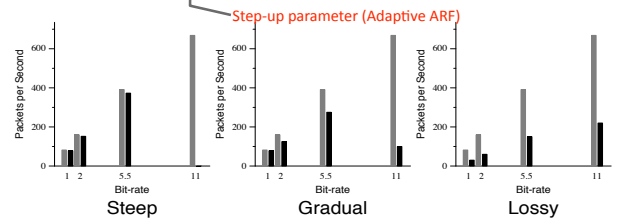
```

1 packet_callback(int num_xmits, bool acked);
2 if num_xmits == 1 then okay_pkt_count++;
3 else okay_pkt_count = 1;
4 if lacked then current_bitrate ↓; return;
5 if okay_pkt_count > 10 then current_bitrate ↑; return;

```

State (per-dest)

current_bitrate
okay_pkt_count



ONOE (madwifi)

Algorithm (Atsushi Onoe)

```

repeat every second, per-destination:
if num_tx > 0 and num_tx_ok = 0
then current_bitrate ↓; init(); return;
if num_tx > 10 and num_tx_ok / num_tx < 0.5
then current_bitrate ↓; init(); return;
if num_tx_ok / num_tx < 0.1 then credits--; return;
if num_tx_ok / num_tx > 0.9 then
credits++;
if credits > 10 then current_bitrate ↑; init();

```

```

init():
num_tx = num_tx_ok = 0;
credits = 0;

```

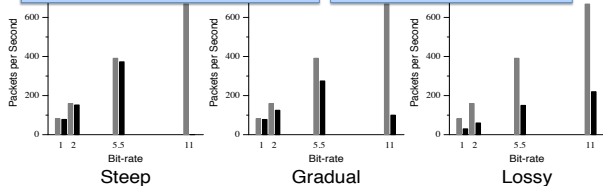
```

packet_callback(bool success, int txcount):
num_tx = num_tx + txcount;
if success then
num_tx_ok++;

```

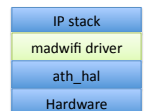
State (per-dest)

credits
current_bitrate
num_tx
num_tx_ok



SampleRate overview

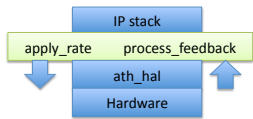
- Basic idea: consider **time to send a packet**
 - Average send time @ bitrate
 - Lossless send time @ bitrate
- Choose bitrate with least *average* send time
- Probe other bitrates
 - Every 10 *packets*
 - Probe **candidate set** of rates.
- Expire information >10 *seconds*



SampleRate state and helpers

State (per-dest, per-rate)

- acks
- successive_failures
- avg_tx_time (packet)
- lossless_tx_time (packet)

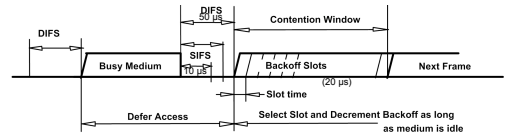


- **apply_rate**
 - No acks yet: pick highest rate without four fails
 - Probe (1/10): pick randomly from candidate set
 - Lowest average transmission time
- **process_feedback(success, txcount)**
 - Calculate send time, update state
- **remove_stale_results**: purge results > 10s old

[Graphic: 802.11-2007 specification]

Measuring time to send a packet

Assume unicast, RTS/CTS is disabled. Let's go to the spec (802.11b DSSS values):

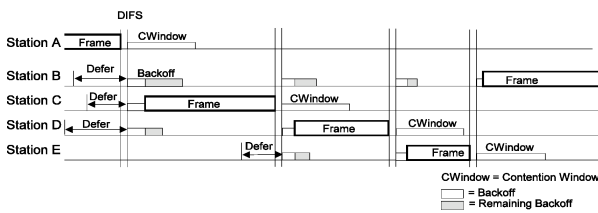


$$tx_time(bitrate, r, N) = DIFS + backoff(r) + (r + 1) \left(SIFS + ACK + HEADER + \frac{8 \cdot N}{bitrate} \right)$$

- **Similar to MACAW**
 - Key difference: **as long as medium is idle**

[Graphic: 802.11-2007 specification]

802.11: pause your backoff countdown



[Table: Bicket, MS thesis '05]

SampleRate in operation

| Destination | Bit-rate | Tries | Packets Ack'ed | Succ. Fails | Total TX Time | Avg TX Time | Lossless TX Time |
|-------------------|----------|-------|----------------|-------------|---------------|-------------|------------------|
| 00:05:4e:46:97:28 | 11 | 16 | 0 | 4 | 250404 | ∞ | 1873 |
| 00:05:4e:46:97:28 | 5.5 | 100 | 100 | 0 | 297600 | 2976 | 2976 |
| 00:05:4e:46:97:28 | 2 | 0 | 0 | 0 | 0 | - | 6834 |
| 00:05:4e:46:97:28 | 1 | 0 | 0 | 0 | 0 | - | 12995 |
| 00:0e:84:97:07:50 | 11 | 28 | 14 | 0 | 52654 | 3761 | 1873 |
| 00:0e:84:97:07:50 | 5.5 | 50 | 46 | 0 | 148814 | 3235 | 2976 |
| 00:0e:84:97:07:50 | 2 | 0 | 0 | 0 | 0 | - | 6834 |
| 00:0e:84:97:07:50 | 1 | 0 | 0 | 0 | 0 | - | 12995 |

Evaluation methodology

Indoor: 45 node a/b/g



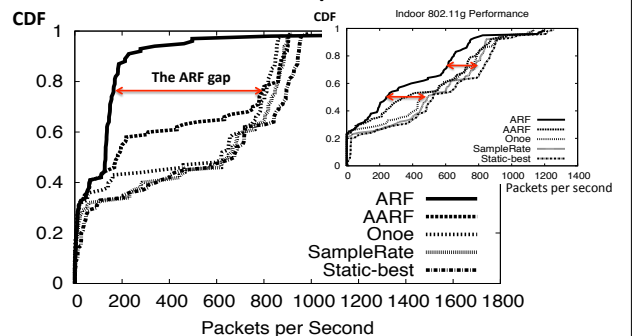
Outdoor: 38 node b/g

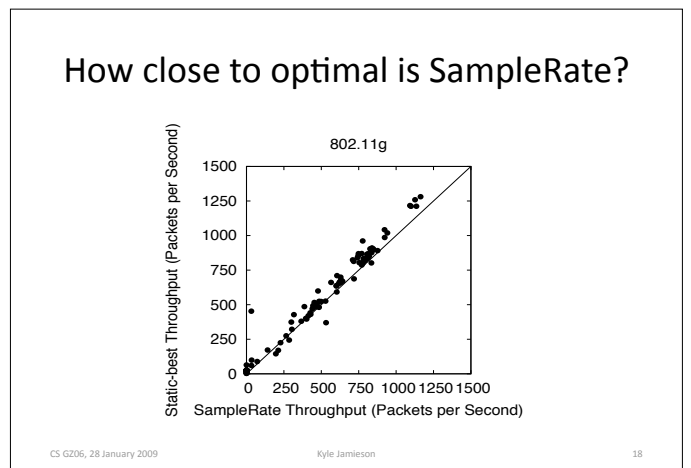
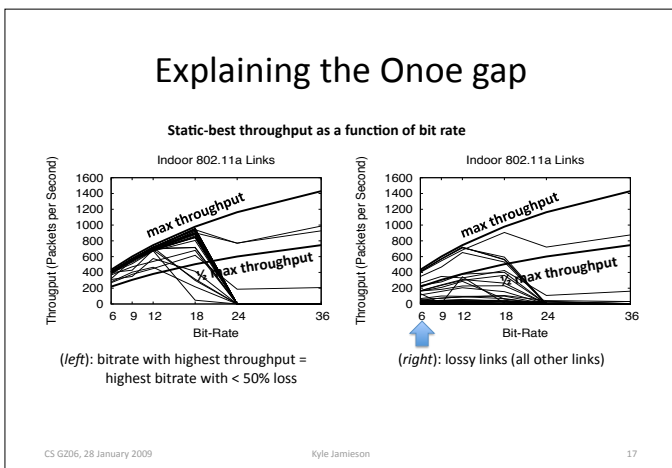
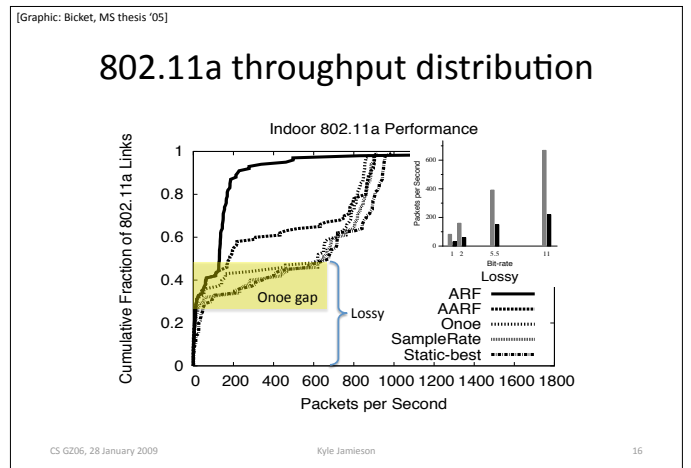
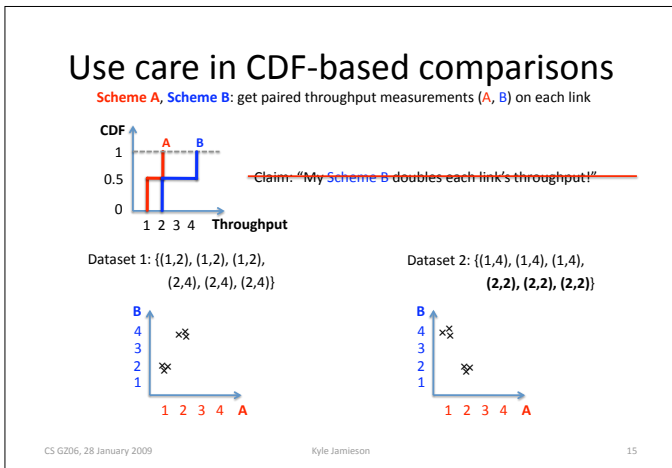
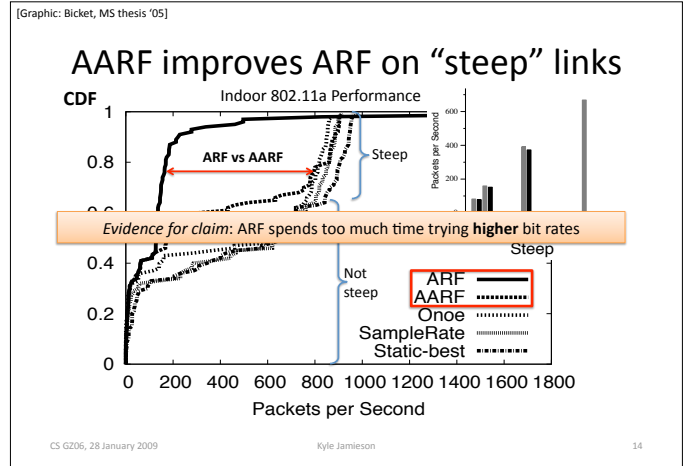
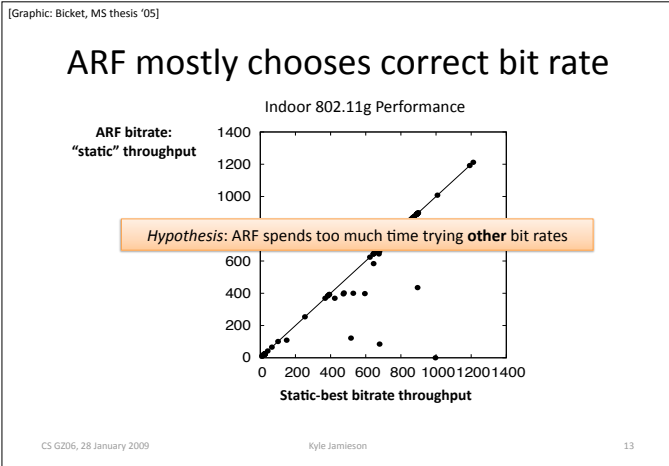


- SampleRate, ARF, AARF, ONOE
- Static best: fix bitrate, "short test"

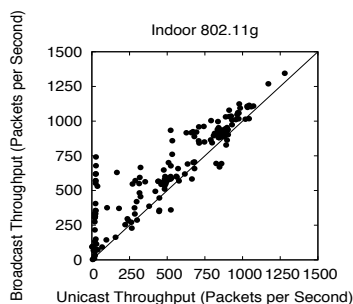
[Graphic: Bicket, MS thesis '05]

Indoor 802.11a performance





The price of delivery confirmation



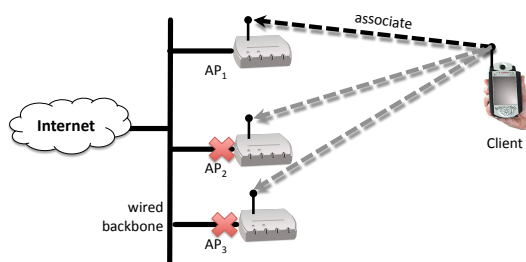
Discussion

- What about interference from other 802.11 traffic?
- What about SNR-based rate adaptation?
 - IS-95 CDMA cellular data (aka 1xEV-DO) uses SNR
 - Why do we have trouble applying it for 802.11?

| | |
|---------------------------|---|
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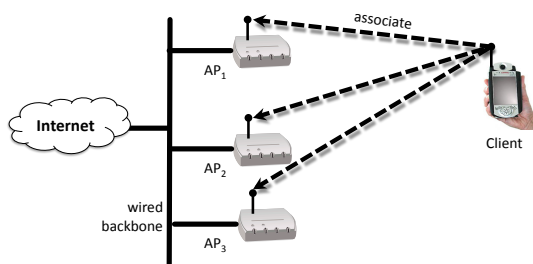
[slide graphics: A. Miu]

Today's wireless LAN (e.g., 802.11)



[slide graphics: A. Miu]

Multi-radio diversity (MRD): basic idea

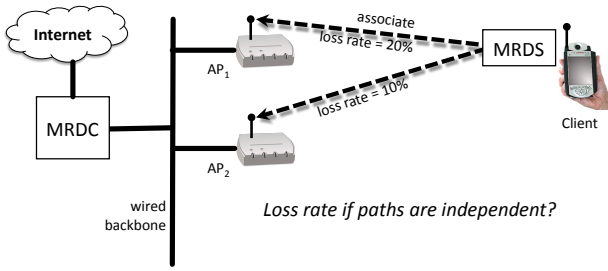


The big wireless picture

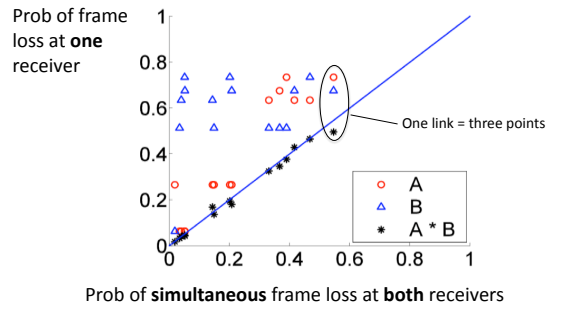
| | | |
|-------------------------|--------------------|------------------|
| Adaptation | Opportunism | Diversity |
| SampleRate: bit rate | | MRD |

- Interplay between rate adaptation and MRD
- Macro-diversity (MRD) vs micro-diversity (MIMO)

Multi-radio diversity (MRD): uplink



Frame losses are independent



Errors are bursty and independent

