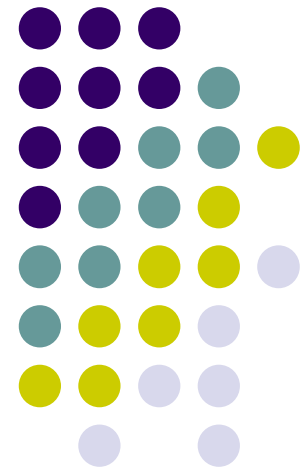


Coexistence Mechanism Using Dynamic Fragmentation

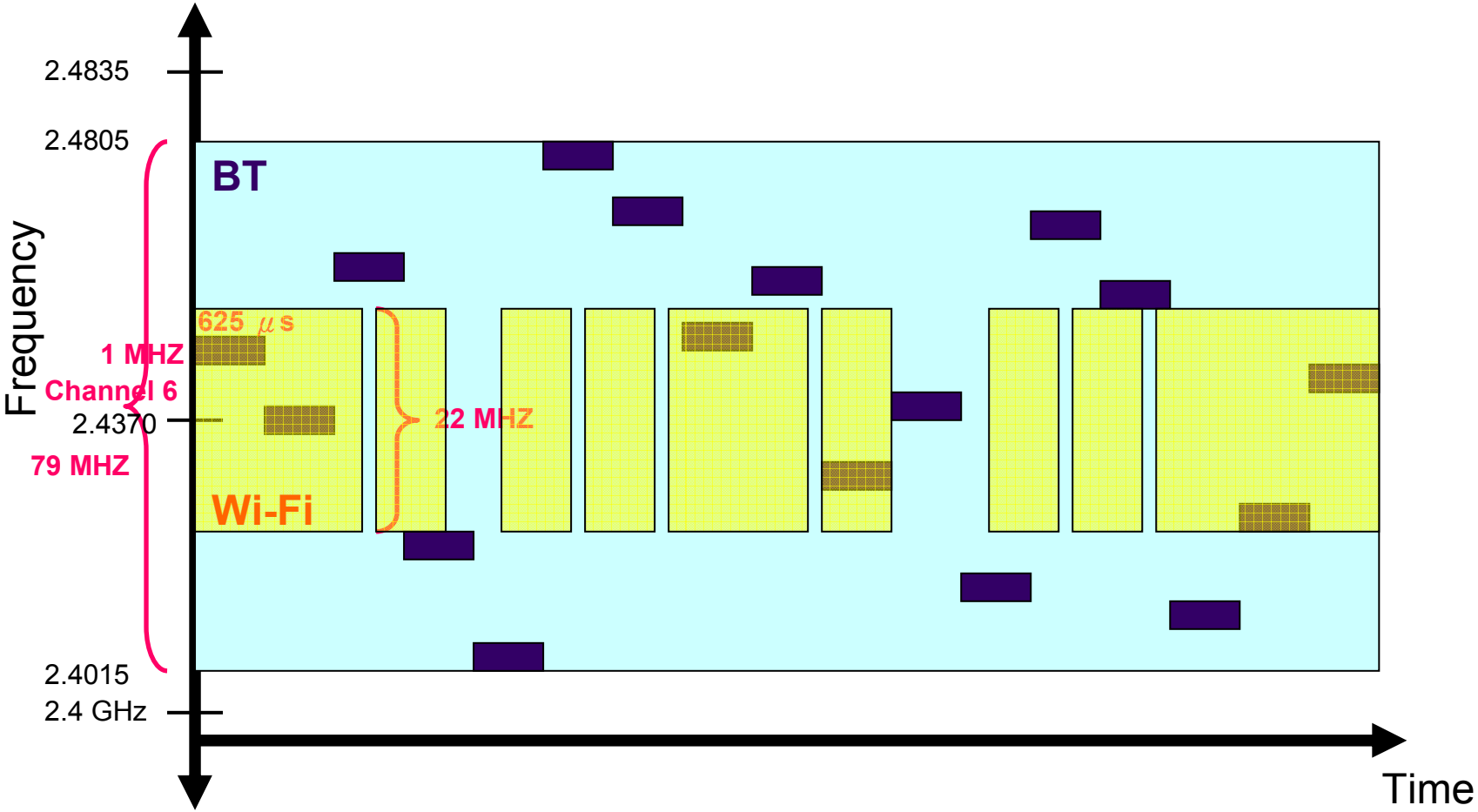
Alex Chia-Chun Hsu

David S. L. Wei

C.-C. Jay Kuo



Overview of Wi-Fi and Bluetooth Coexistence in the UL band



Overview of Wi-Fi and Bluetooth

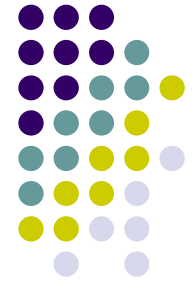
Coexistence in the UL band



- Packet loss caused by interference
 - Overlap both in time and in frequency
 - Over the SNR threshold

Previous Work

Fragmentation



No fragmentation



2 fragments



Previous Work

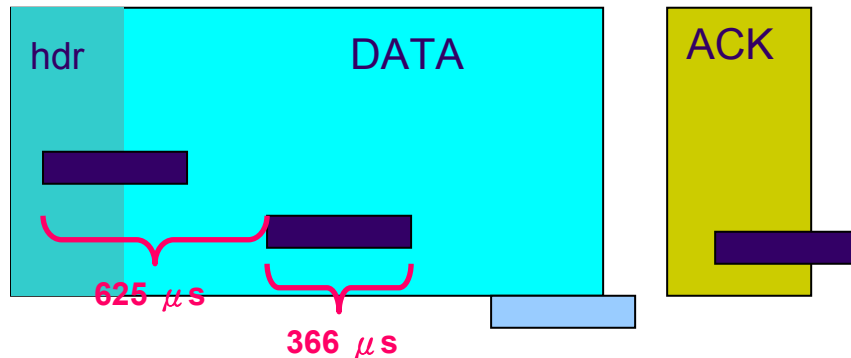
Fragmentation



- Adaptive Fragmentation from 802.15.2 2001
 - Adjust fragmentation according to Packet Error Rate PER
 - Many rounds before reach optimal length
- Optimal Fragmentation by Howitt 2005
 - Complexity is too high to determine the optimal fragment length at run time
- 👁 No resolution on *collision* and *interference*
- 👁 Need simple run time solution with resolution

Dynamic Fragmentation Algorithm

Interference model



$$PER_{Wi-Fi} = 1 - (1 - P_f \tau_{BT} \sigma)^N \approx NP_f \tau_{BT} \sigma$$

P_f : Probability of BT hops on Wi-Fi frequency

N : # of BT time slot overlapped by Wi-Fi packet

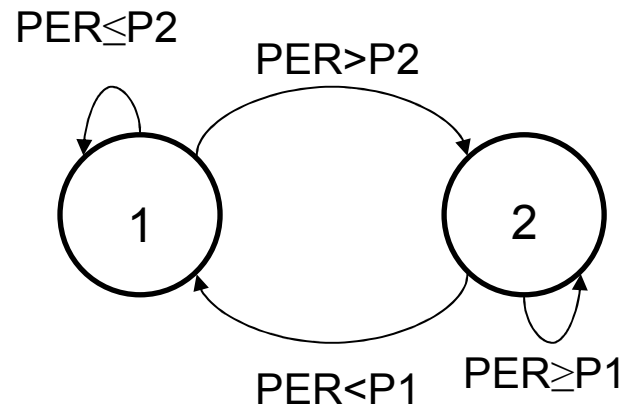
τ_{BT} : Traffic load of BT

σ : utilization of BT time slot

N is crucial

Dynamic Fragmentation Algorithm

State Diagram of DFA



- 2 states
- State 1, no fragmentation
- State 2, DATA → **n** fragments
- PER greater than **P2**, one state up if possible, further fragmentize
- PER lower than **P1** → one state down if possible
- 👁️ How to choose P1, P2?

Dynamic Fragmentation Algorithm

Determine Threshold



$$DIFS + BW + T_h + T_{DATA} + SIFS + T_{ACK}$$



$$DIFS + BW + \frac{T_{DATA}}{n} + SIFS + T_{ACK} + SIFS + T_h + \frac{T_{DATA}}{n} + SIFS + T_{ACK}$$

Retransmission

$$T_{oh} = T_h + 2 \times SIFS + T_{ACK}$$



Double the backoff window

$$DIFS - SIFS + BW + T_{oh} + \frac{T_{DATA}}{n}$$



Dynamic Fragmentation Algorithm

Determine Threshold

Time to transfer a packet with n fragments and suffer R retransmissions

$$\{(R+1)(DIFS + SIFS) + \sum_{i=1}^n BW_i + (n+R)(T_{oh} + \frac{T_{DATA}}{n}) + BW + T_{oh} + \frac{T_{DATA}}{n}\}$$

Compare the transmission time before and after state transition

$$(R+1)(DIFS - SIFS) + \sum_{i=1}^n BW_i + (n+R)(T_{oh} + \frac{T_{DATA}}{n})$$



If true, then state transition is beneficial

$$(R'+1)(DIFS - SIFS) + \sum_{i=1}^{n'} BW_i + (n'+R')(T_{oh} + \frac{T_{DATA}}{n'})$$

Dynamic Fragmentation Algorithm

Determine Threshold



Before state transition

$$E[R] = n \times E[R_i] = n \times \frac{p}{1-p}$$

P is the current PER

Assume geometric distribution

$$E[\sum_R BW_i]$$

Case 1: less or equal to BW upper-bound

$$\frac{1}{2} (2^{a+1} (2^{E[R_i]} - 1) - E[R_i]) \times nT_{slot}$$

$$CW_{\min} = 2^a - 1$$

$$CW_{\max} = 2^b - 1$$

Case 2: greater than BW upper-bound

$$\frac{1}{2} (2^{a+1} (2^{b-a} - 1) - 2^b (b-a) + (2^b - 1) E[R_i]) \times nT_{slot}$$

Dynamic Fragmentation Algorithm

Determine Threshold



How to find PER after state transition?

$$PER_{Wi-Fi} \approx NP_f \tau_{BT} \sigma$$

$$\frac{p}{p'} = \frac{N}{N'} \rightarrow p' = \frac{N}{N'} p$$

$$E[R'] = \frac{n' p'}{1 - p'} = \frac{n' p}{\frac{N}{N'} - p}$$

$$E[\sum_{R'} BW_i] \quad \text{Same as previous slide}$$

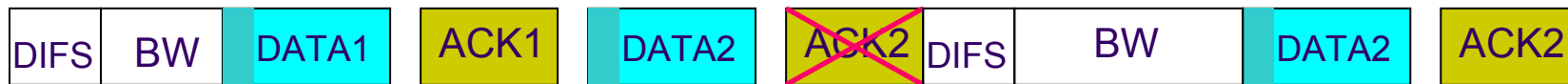
Now we have all the parameters to calculate a theoretically correct threshold

Dynamic Fragmentation Algorithm Optimization



Wi-Fi	Collision	Interference
Timing	From the beginning of a transmission	Most likely not
Cause	Traffic Jam	Coexistence (BT)
Solution	CSMA/CA	Coexistence Mechanism

👁️ Transmission failure on following fragments is due to Interference



With optimization



Dynamic Fragmentation Algorithm Optimization



Only first fragment needs backoff window when retransmission

$$(R + 1)(DIFS - SIFS) + \sum_{1+r} BW_i + (n + R)(T_{oh} + \frac{T_{DATA}}{n})$$



If true, then state transition is beneficial

$$(R' + 1)(DIFS - SIFS) + \sum_{1+r'} BW_i + (n' + R')(T_{oh} + \frac{T_{DATA}}{n'})$$

DFAm : without optimization

DFAs : with static optimization

Result Simulation

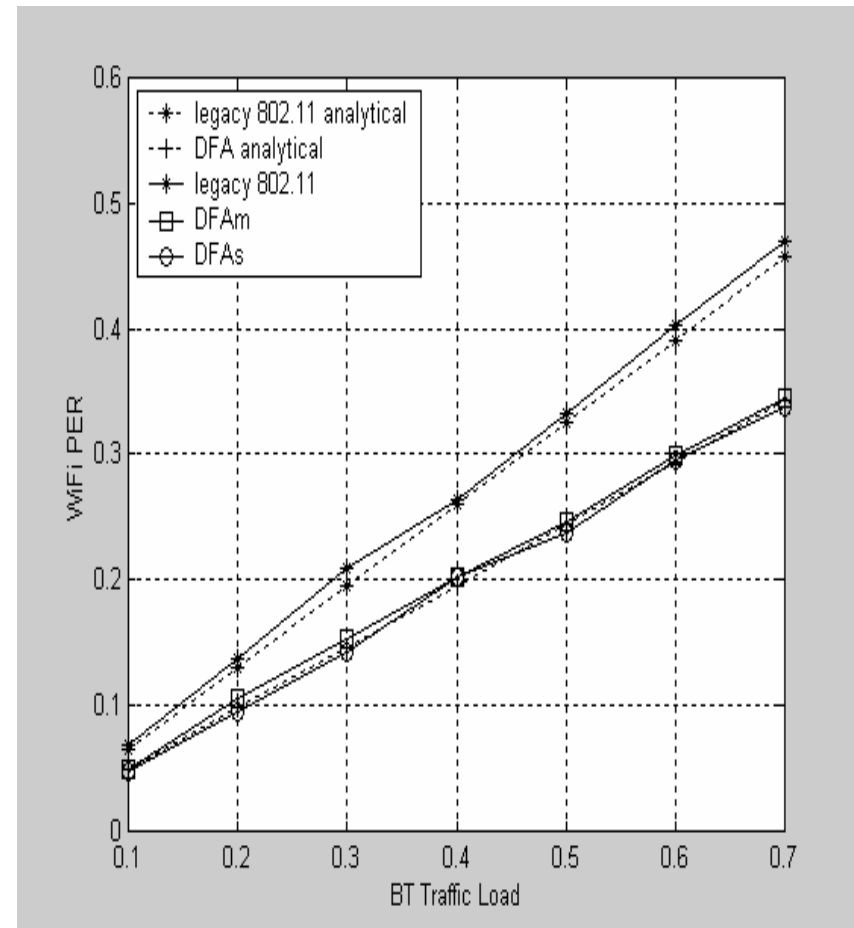


Parameter	Assigned Value
SlotTime	20 μ s
DIFS	50 μ s
SIFS	10 μ s
PHY header	192 bits
MAC header	224 bits
Payload	12000 bits
ACK	112 bits
CW_{min}	32
CW_{max}	1024

TABLE II
802.11 WLAN PARAMETERS

Parameter	Assigned Value
T_B	625 μ s
T_{BA}	366 μ s

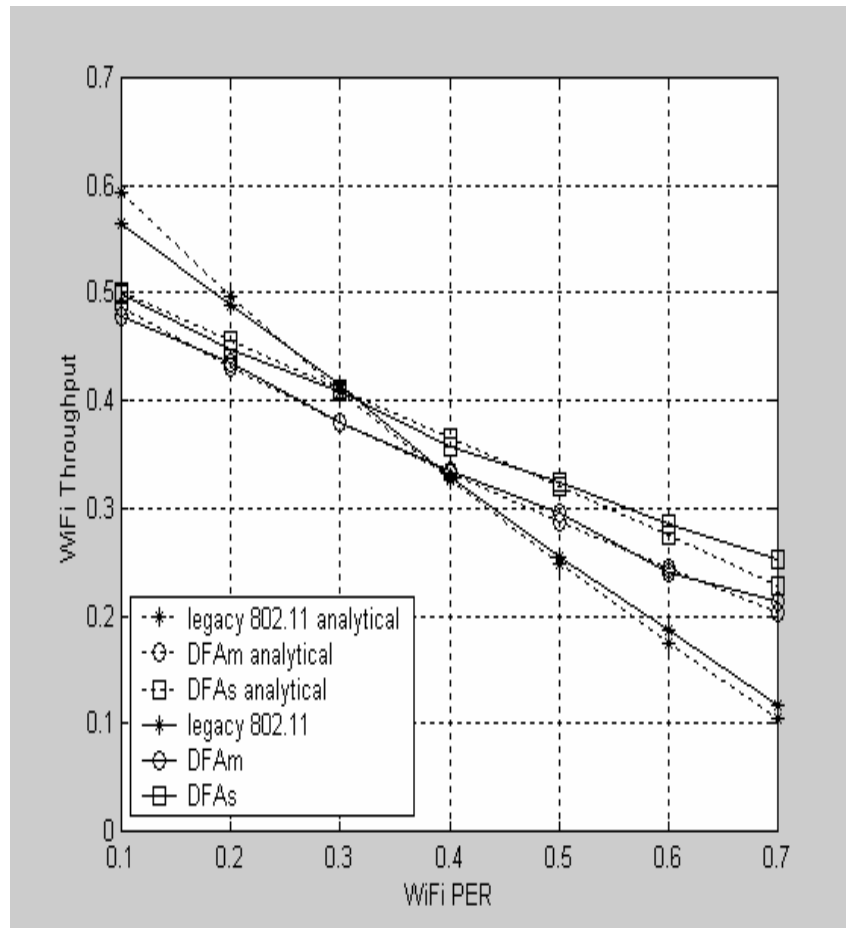
TABLE III
BLUETOOTH PARAMETERS



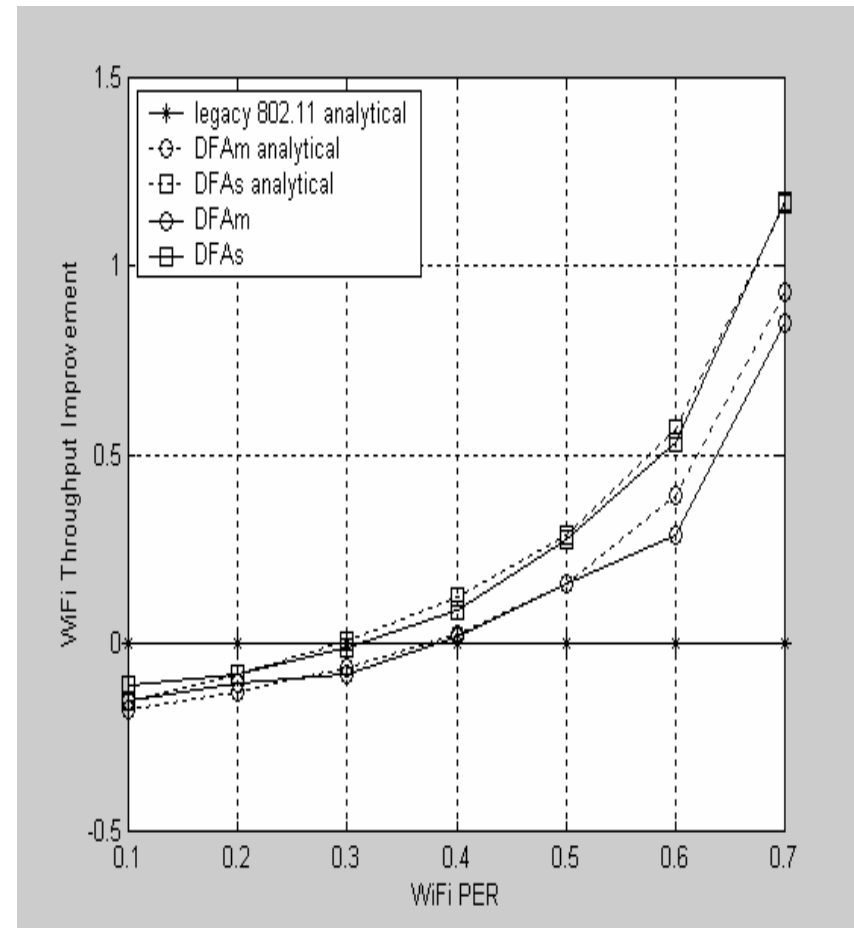
PER equation validation

Result

Simulation



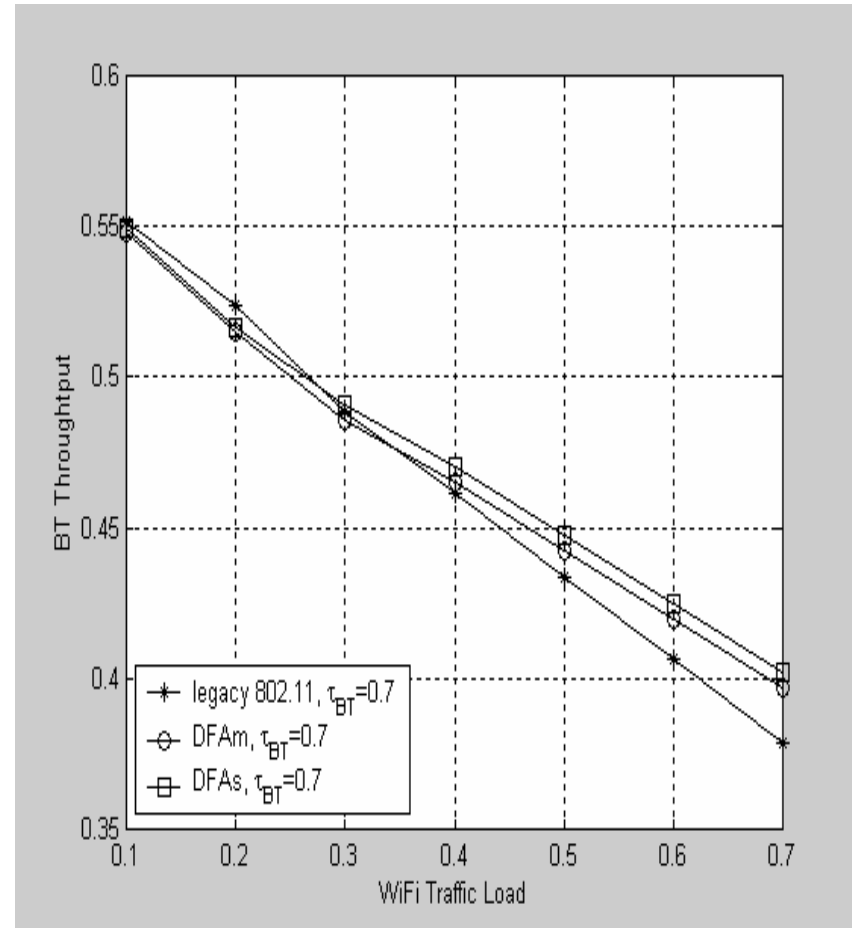
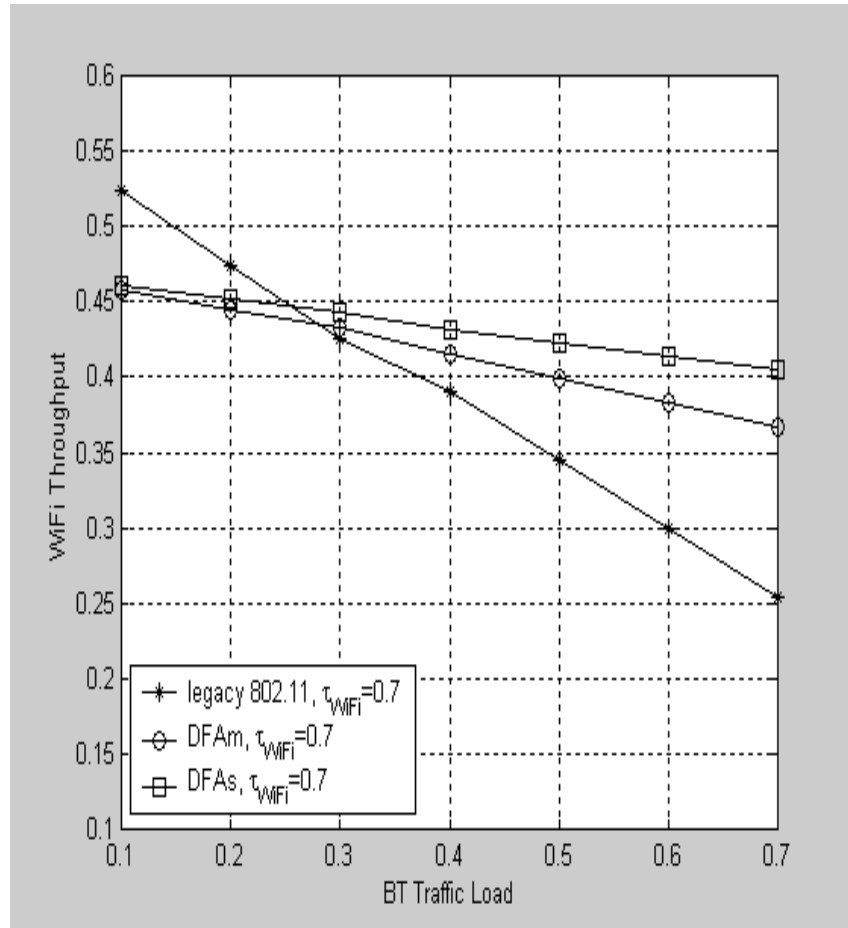
Threshold equation validation



Throughput improvement

Result

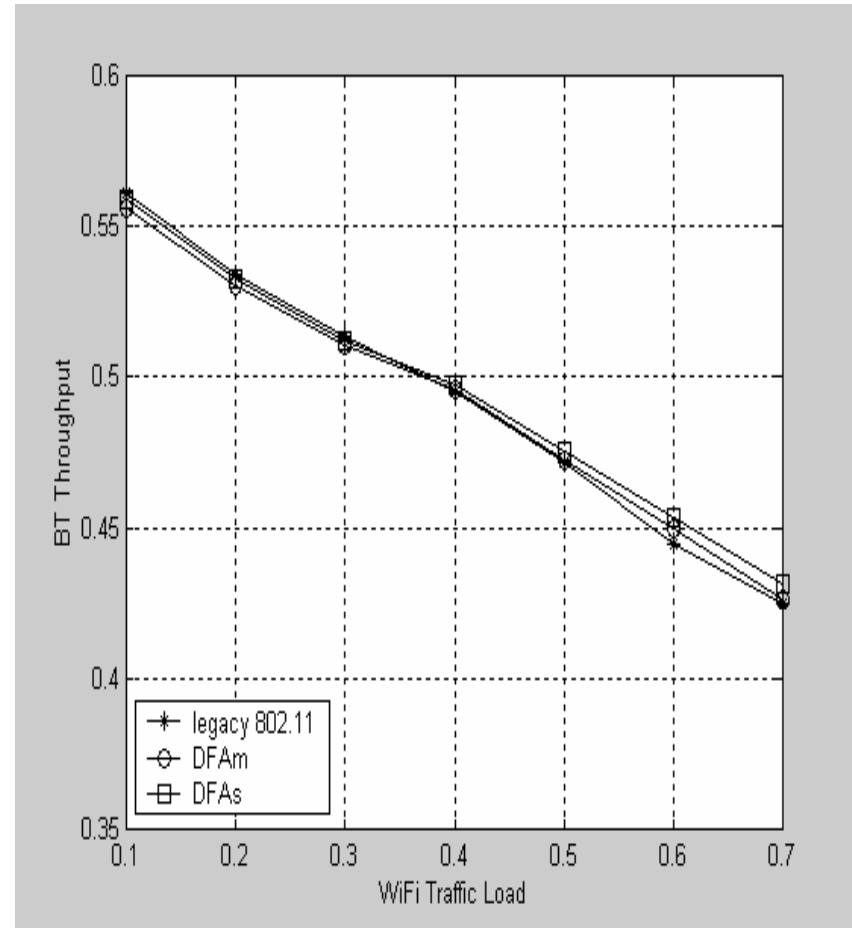
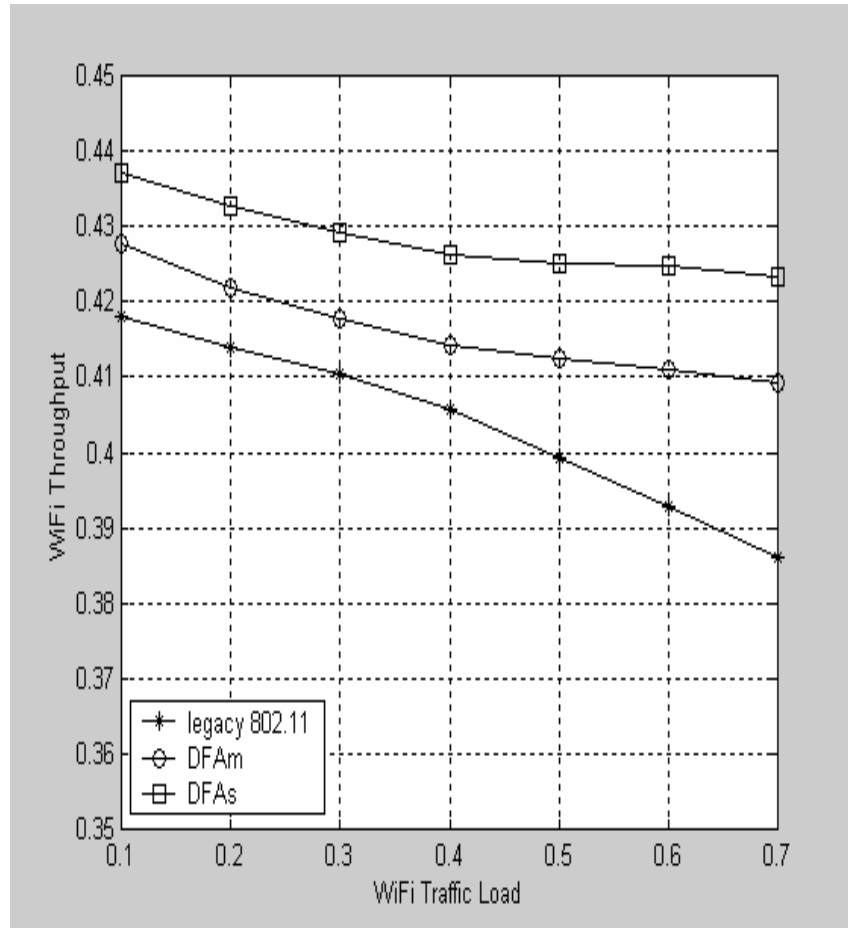
Simulation: ACL link



Throughput of the Wi-Fi and BT in the presence of BT ACL link

Result

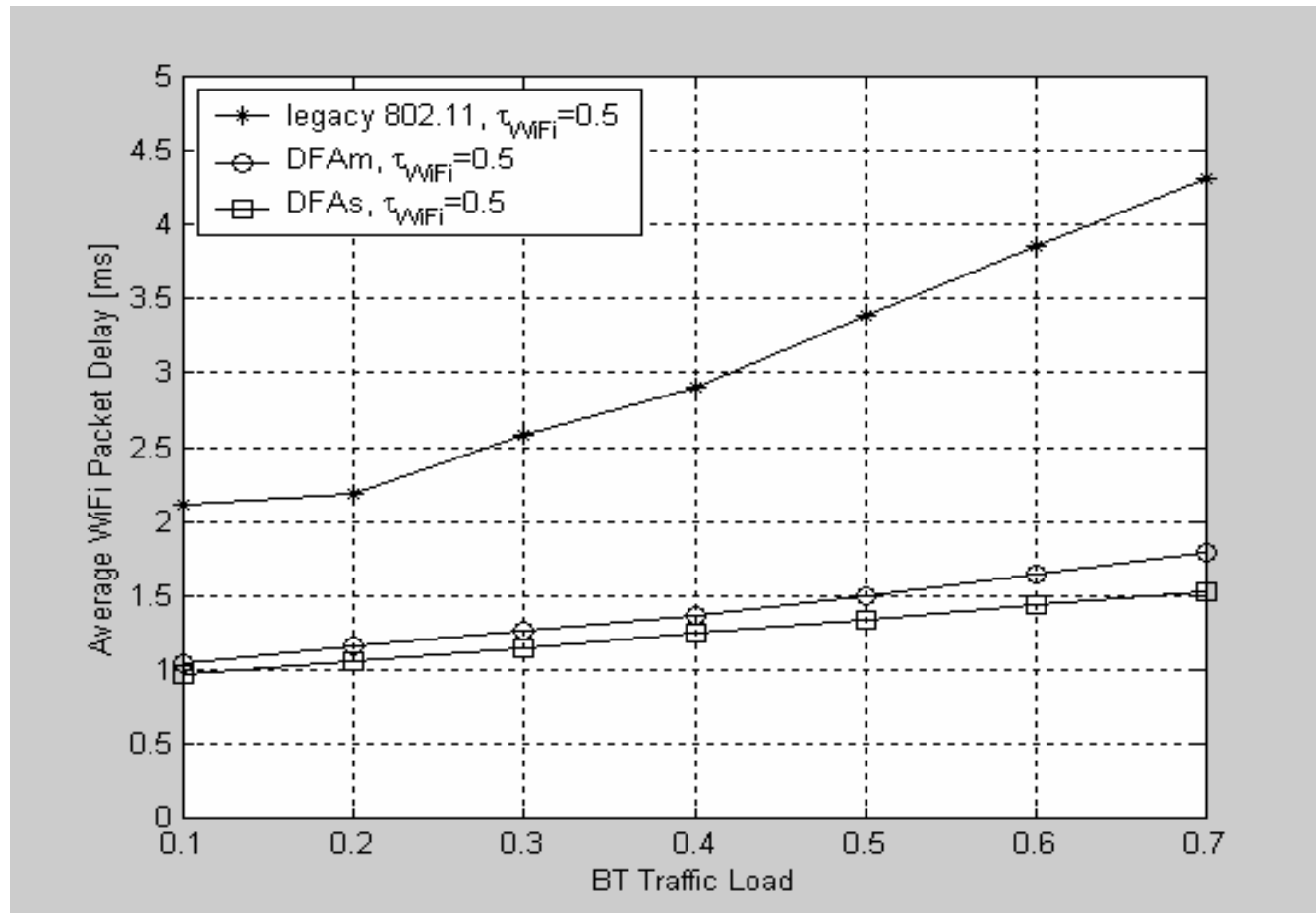
Simulation: 2 SCO links



Throughput of the Wi-Fi and BT in the presence of 2 SCO links between BT master/slave

Result

Simulation: delay



Average Wi-Fi delay vs. BT traffic load

Conclusion and Future work

Conclusion



- Simple non-collaborative mechanism
 - Increase *collision/interference* resolution
 - Improve throughput and delay
 - Built a reliable, powerful model
- If PER > 0.6,
DFAs 56%, DFAM 30%