Self-learning Collision Avoidance for Wireless Networks

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Outline

- Introduction
- Hidden/exposed terminal problem
- Self-learning collision avoidance
- Performance evaluation
- Conclusions

Introduction

- Neighboring 802.11 basic service sets often interfere with each other because of the limited number of orthogonal channels
- The 802.11 MAC does not work well in resolving inter-BSS interferences due to the hidden/exposed receiver problem
- The author proposes SELECT, an effective and efficient self-learning collision avoidance strategy to address the hidden/exposed receiver problem

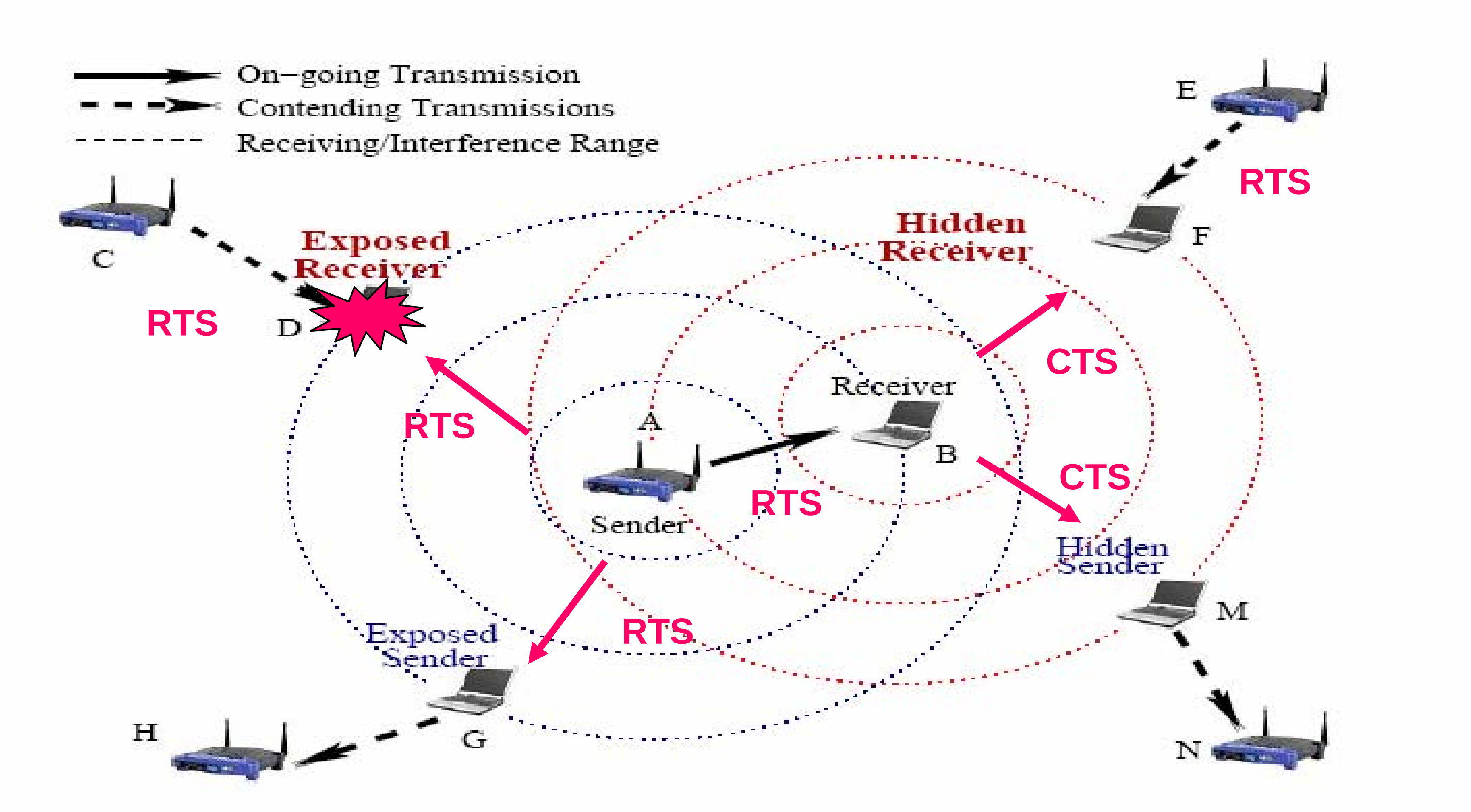
Hidden/exposed terminal problem

- Hidden/exposed terminal problem
  - Hidden/exposed sender
  - Hidden/exposed receiver

- 802.11 DCF's RTS/CTS handles the hidden/exposed sender problem well

- No existing solutions handle the hidden/exposed receiver problem within single-channel operation

Hidden/exposed terminal problem



Consequences

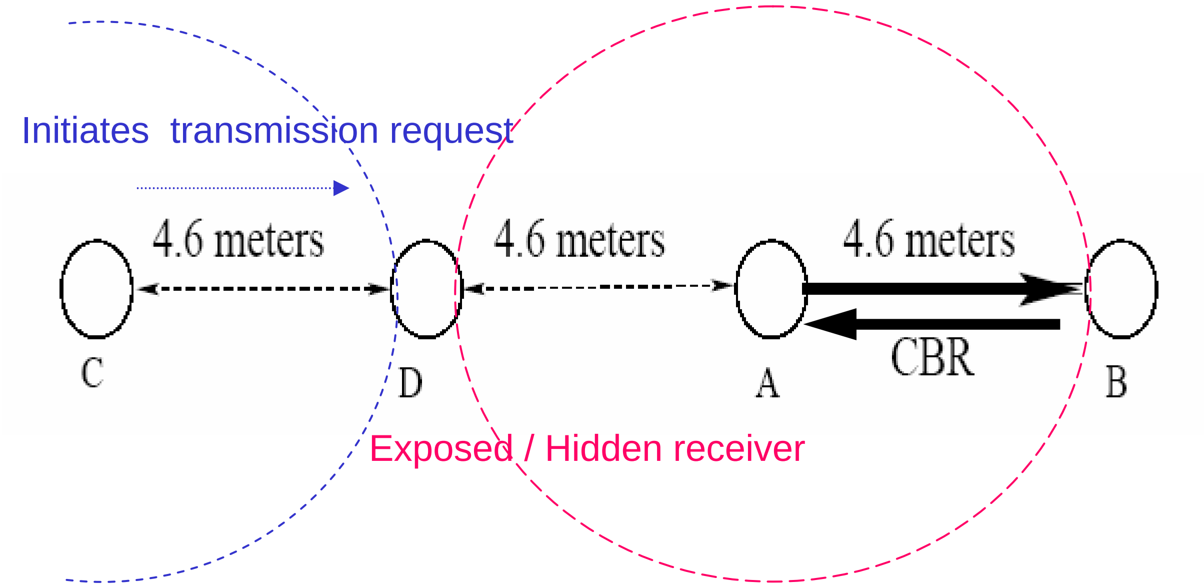
- Packet loss
- Unsuccessful RTS attempts might mislead the sender to the conclusion that the intended receiver is unavailable or the channel quality at the receiver side is low
  - Routing instability
  - Data rate reduction
- Unfair channel access
- Low shared channel utilization

Self-learning collision avoidance

- Challenge
  - Lack of efficient mechanisms to exchange channel availability information between the sender and the receiver, before a channel access attempt is made
- Solution
  - SELECT, a self-learning collision avoidance mechanism, to address hidden/exposed receiver problem in wireless networks
  - SELECT is based on the strong correlation between sender/receiver received signal strength (RSS) can be exploited for collision avoidance

C2

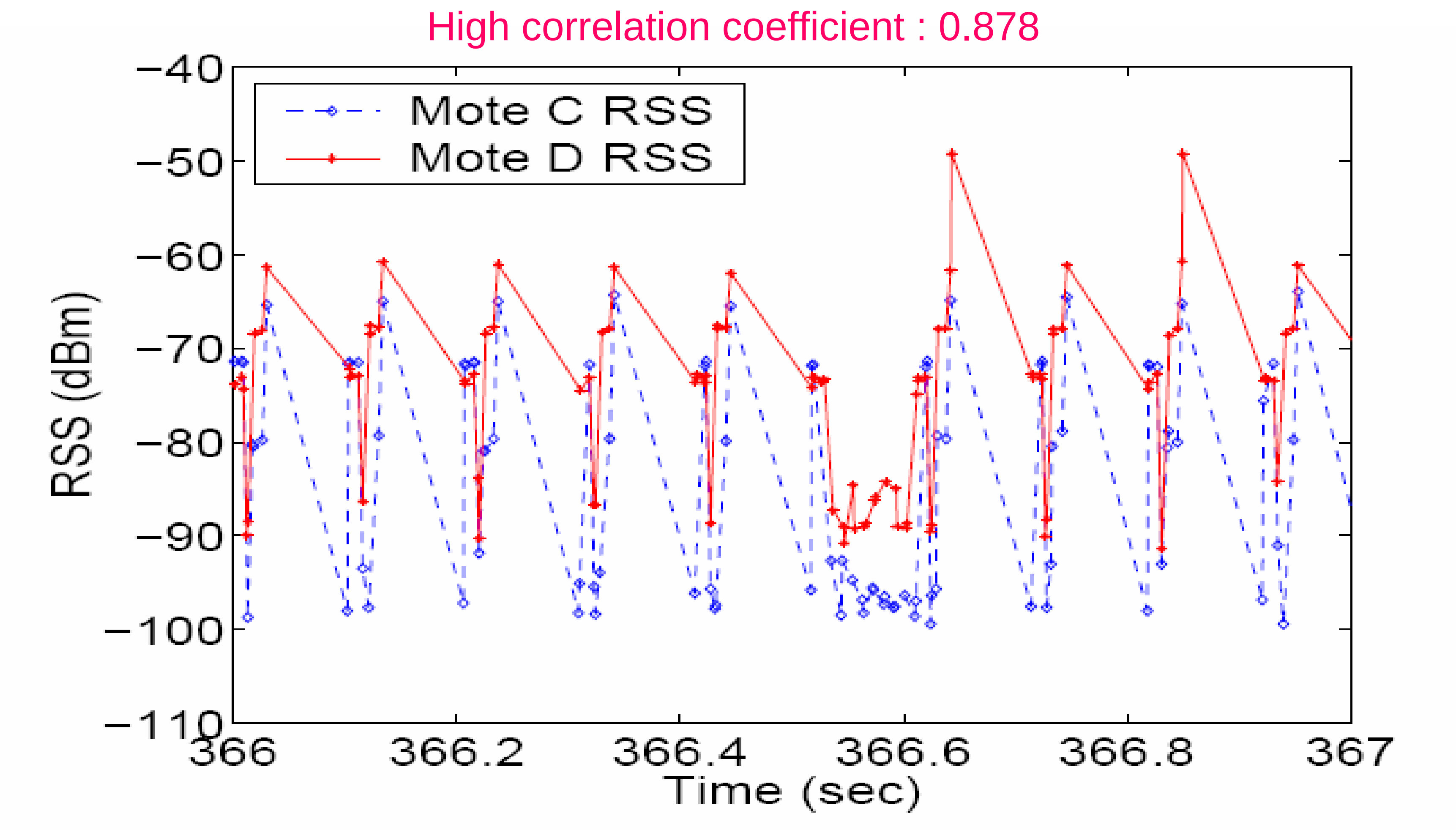
Sender/receiver RSS correlation



To study the relationship between the RSS at a potential sender (C) and the RSS at an exposed receiver (D)

C2　　在interfernce area所測得之RSS measurements都會顯示高度的相關性,可以反映出來自相同干擾源的無線訊號接受的情形
Customer, 2006/7/27

RSS at C & D

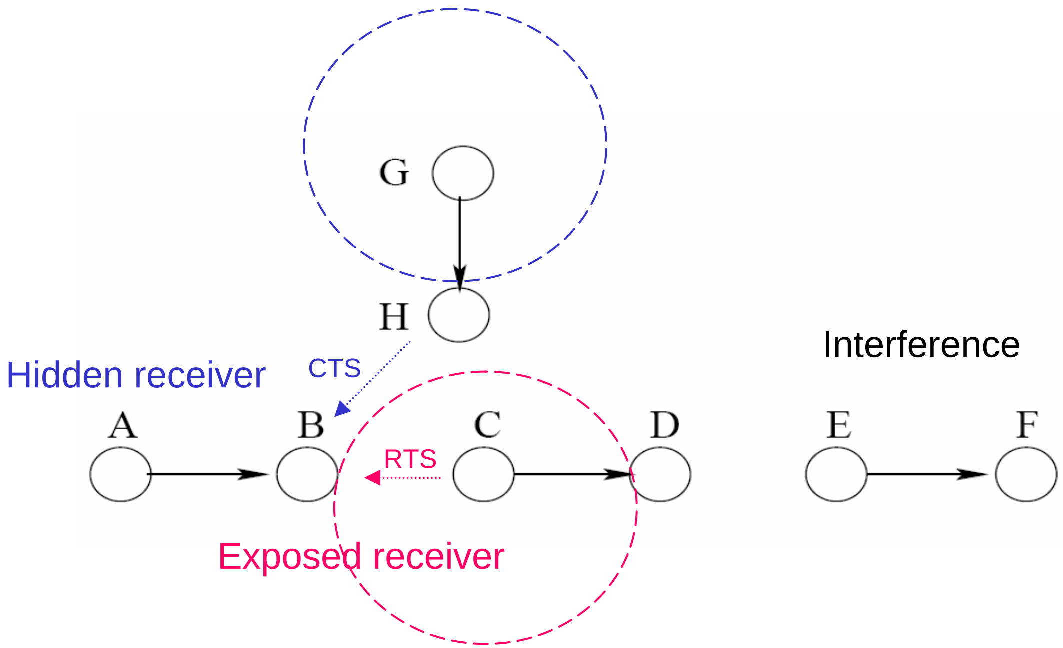


High correlation coefficient : 0.878
Mote C RSS
Mote D RSS
RSS (dBm)
−40
−50
−60
−70
−80
−90
−100
−110
366
366.2
366.4
366.6
366.8
367
Time (sec)

Summary

- The transmission between A and B may not be strong enough to be decoded at all nodes in the area (e.g, node C), it is strong enough to dominate their RSS's in the presence of noises and interferences
- The RSS measurements in the interference area will exhibit strong correlations, reflecting their receptions of the wireless signals from the same sources of interferences

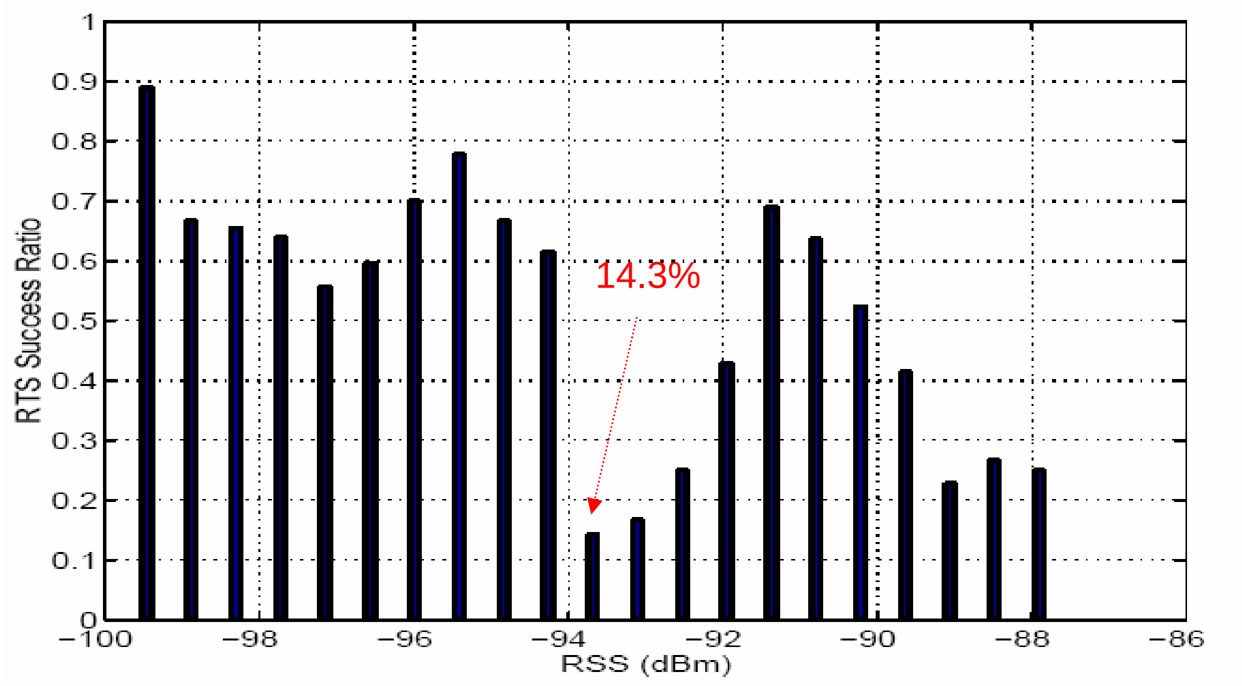
RSS v.s. Success ratio



Log the RSS at sender A ：

- Before it initiates channel access (with RTS)
- The success reception of CTS or failure

RSS v.s. RTS Success ratio at A



$$\text{Success ratio} = \frac{\text{The number of successful CTS messages}}{\text{Total number of RTS attempts}}$$

Summary

- The relationship between the sender's RSS and the corresponding channel access success ratio is not monotonic

C1

- A carrier sense with low RSS at the sender (A) does not necessarily mean the channel is available at the receiver (B)

C1 當A的RSS很低,意味著可能離其他人的傳輸距離很遠,但未必保證B的channel是可用的
此時,B可能是隱藏節點或暴露節點
Customer, 2006/7/27

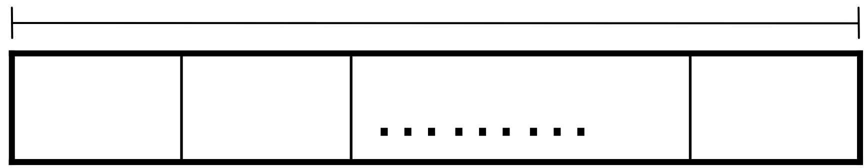
Self-learning collision avoidance

- The sender directly establish the mapping between its RSS and the success ratio of its channel access attempts and decide whether it makes channel access
  - RSS-SR mapping maintenance
  - RSS-SR mapping lookup

RSS-SR mapping maintenance

N = [RSS_i^{min}, RSS_i^{max}]

Histogram



$$\boldsymbol{I_i = < S_i, F_i, T_i^{udp} >}$$

S_i ：the number of successful channel access attempts

F_i ：the number of failed channel access attempts

T_i^{udp} ：the last time S_i and F_i are updated

Mapping Update

- Upd_RSS_SR (*rss*, *sf*)

1. Locate element $I_i \rightarrow i = \lfloor (rss - RSS^{min}) / I_{width} \rfloor$

2. Adaptive aging factor $\rightarrow \alpha = 1-(t - T_i^{udp}) / T_{win}$

3. If (*(t- Tiudp) > Twin)* *clear* S_i *and* F_i $\rightarrow$ If ($\alpha < 0$) *then* $\alpha = 0$;

4. channel access succeeds → if (sf == 1) then S = 1; F = 0; or
   channel access fails → if (sf == 0) then S = 0; F = 1; or
   no new record → if (sf == -1) then S = 0; F = 0;

5. Update # of successful attempts $\rightarrow S_i = \alpha \times S_i + S$;

6. Update # of failed attempts $\rightarrow F_i = \alpha \times F_i + F$;

7. Update timestamp $\rightarrow T_i^{udp} = t$;

RSS-SR mapping lookup

- RSS_SR_LookUp (rss)

1. Is channel busy at sender ? → if (rss >= CS_{thred}) return 0%;

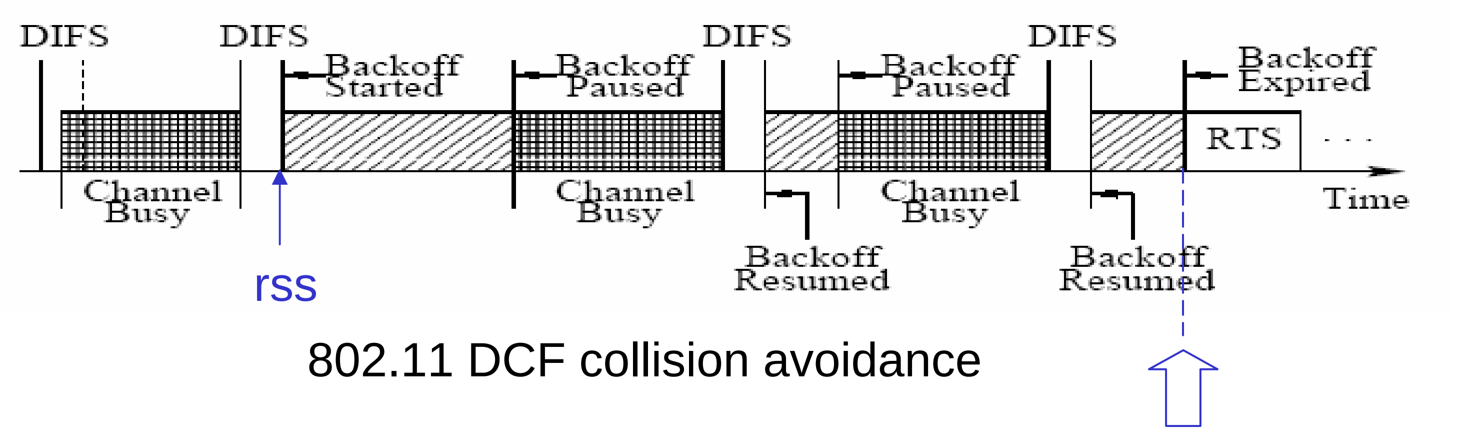
2. Remove outdated records → Upd_RSS_SR(rss,-1)

3. Locate element I_i → $i = \lfloor (rss - RSS^{min}) / I_{width} \rfloor$

4. Is Enough records ? →

```
if (S_i + F_i > Min_Num_Rec)
    return S_i / (S_i + F_i); // Success ratio
else
    return 100%; // Channel is idle by default
```

Integration with 802.11 DCF



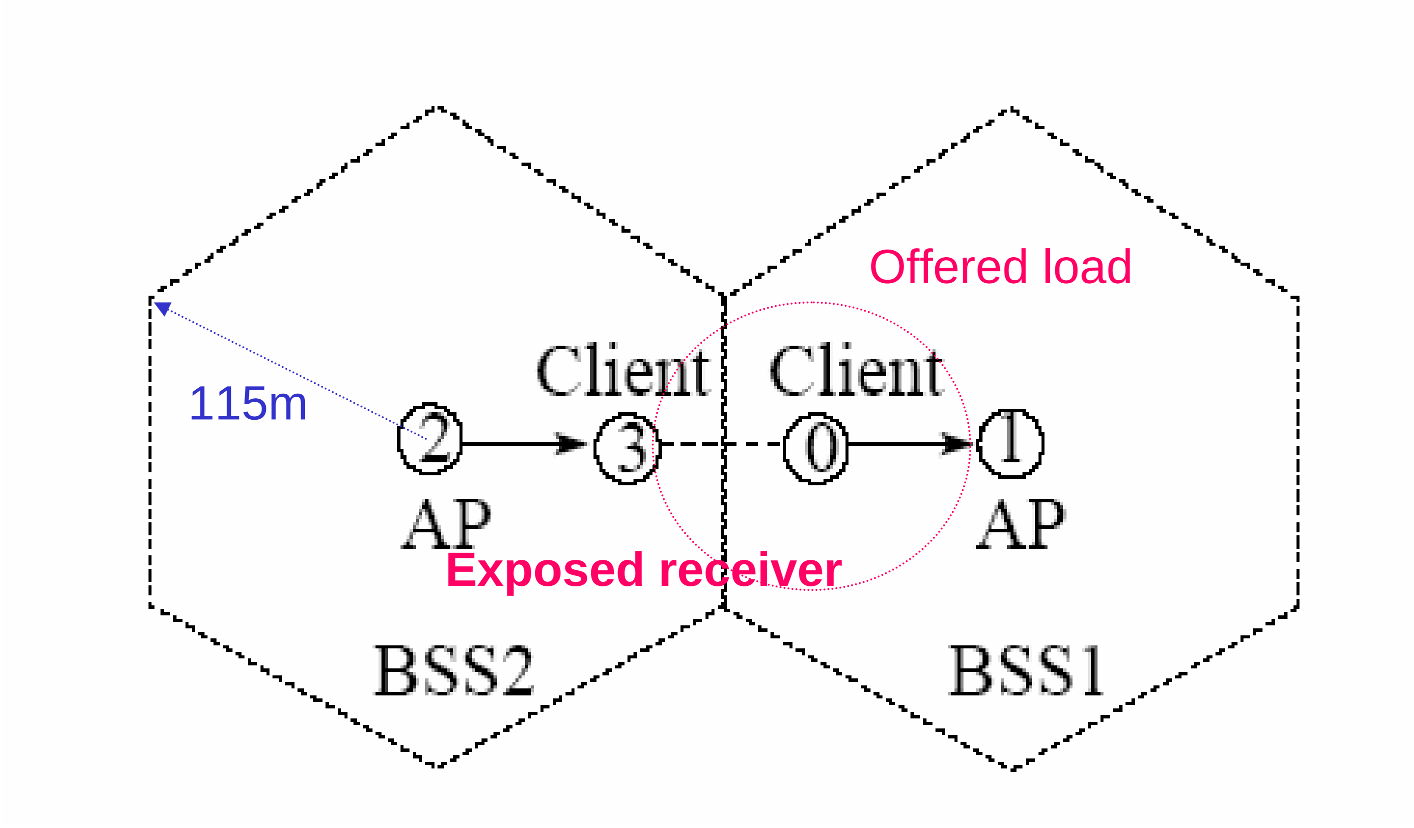
802.11 DCF collision avoidance

SELECT is Integrated with 802.11 DCF →
Sender measures the RSS and call RSS_SR_LookUp

Success ratio is high → Sender proceeds to contend for channel
Success ratio is low → Channel access failure (improvement~10%)

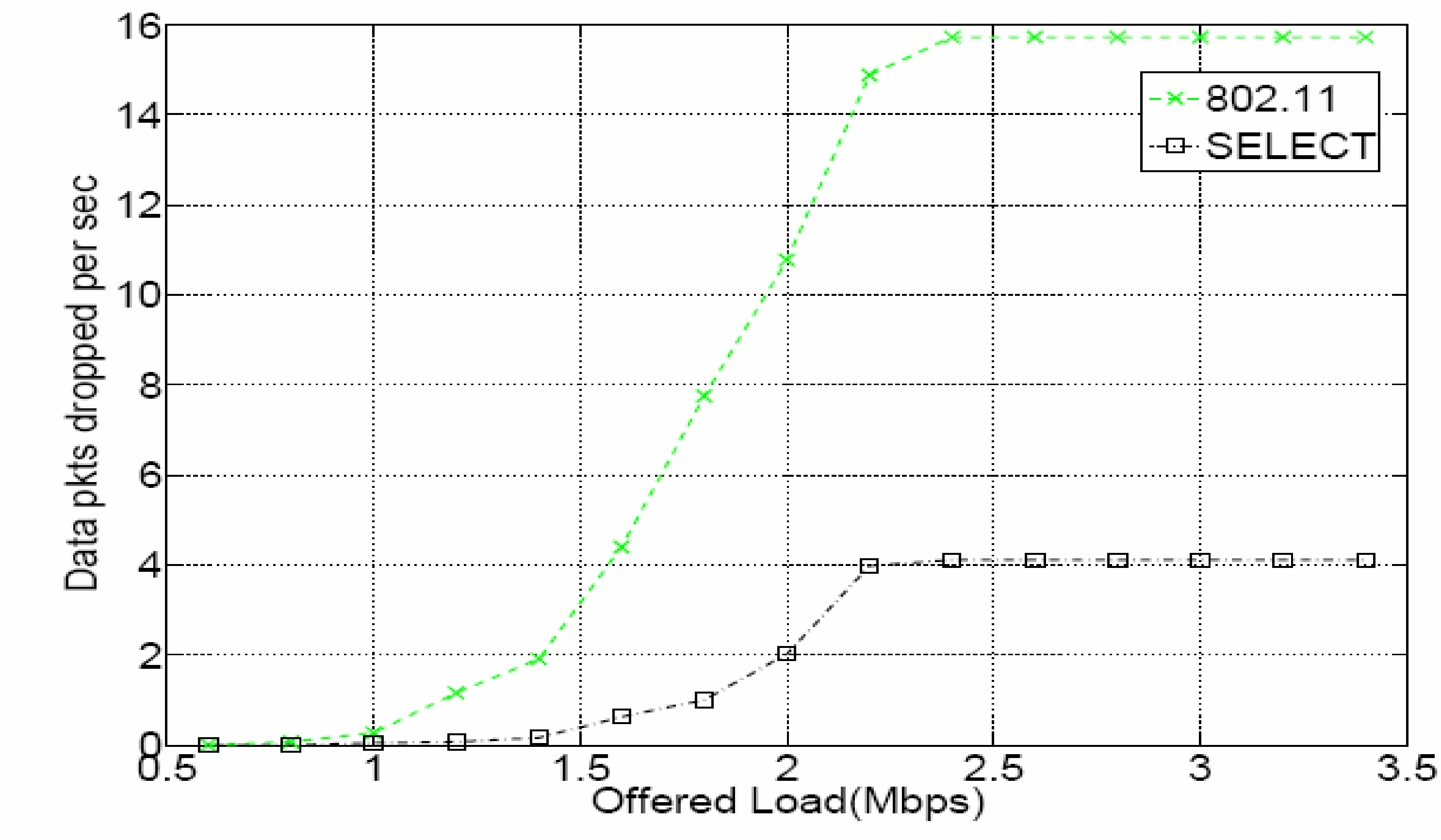
→ The sender *suspends its backoff timer whenever success ratio is low, and resume the backoff timer whenever success ratio is high*

Performance evaluation



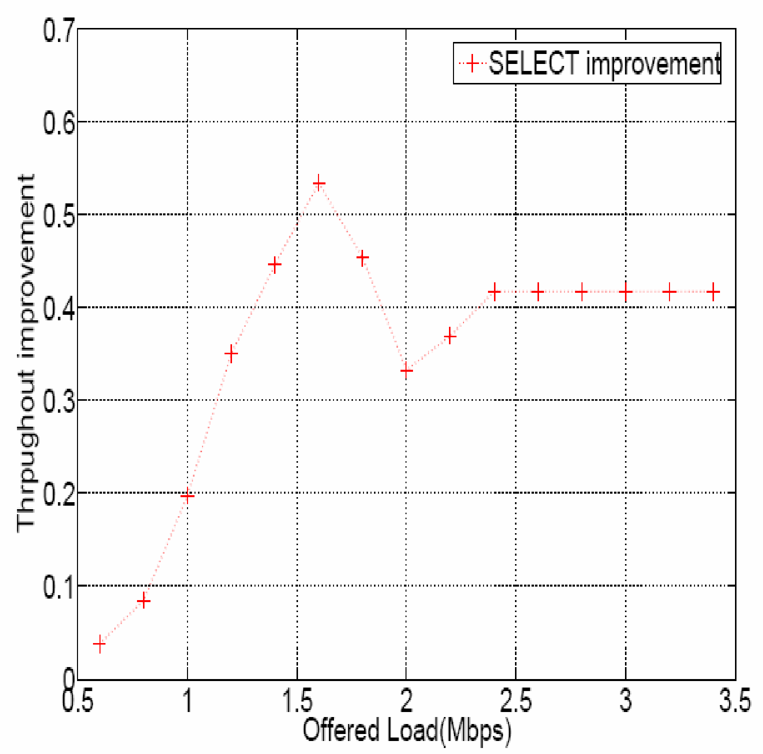
Exposed receiver problem

Data packet drop at node 2

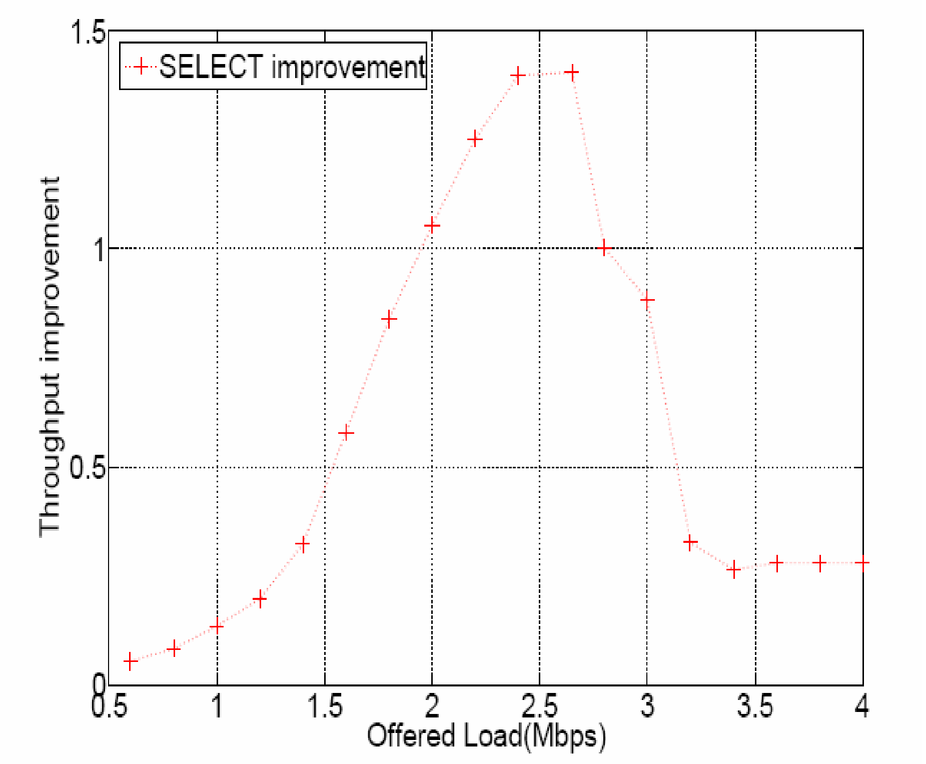


(w/ RTS/CTS)

Throughput gain at node 2

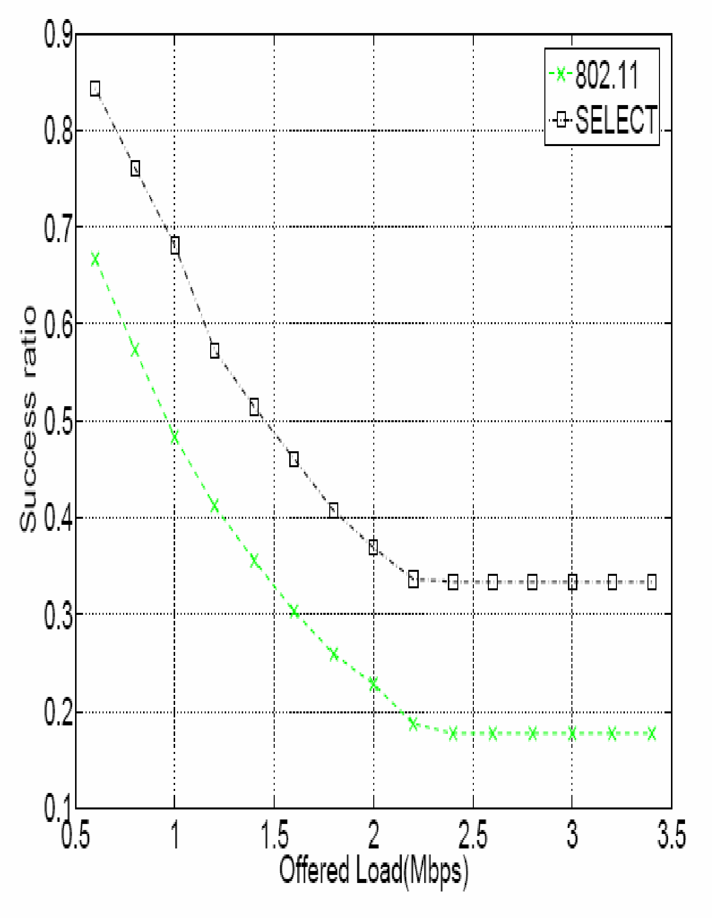


(w/ RTS/CTS)

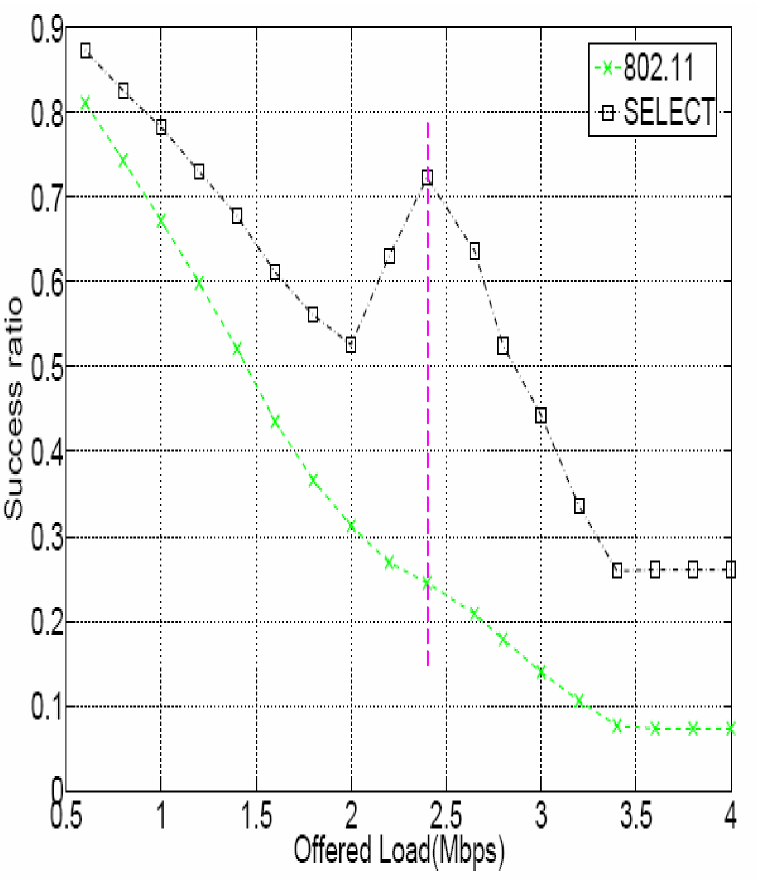


(w/o RTS/CTS)

Success ratio at node 2



(w/ RTS/CTS)



(w/o RTS/CTS)

Conclusions

- SELECT is an effective and efficient self-learning collision avoidance to tackle the long-haunting hidden/exposed receiver problem

- In hidden/exposed receiver scenarios, SELECT improves the throughput about 140% and channel access success ratio about 302%, while almost completely eliminating contention-induced data packet drops