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On the Use of Radio Resource Tests in Wireless ad hoc Networks

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1 On the Use of Radio Resource Tests in Wireless ad hoc Networks 28/06/09

Road Map

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➤ Introduction
Radio Resource Tests
Analysis
Summary

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Introduction – Wireless ad hoc Networks


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Securing Wireless ad hoc Networks is particularly difficult


- Denial-of-service
- Eavesdropping
- Node hijacking
- Impersonation
 - Sybil Attack



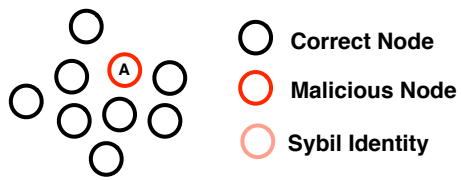
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Introduction – The Sybil Attack


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A Sybil attack happens when a malicious node participates with multiple identities in a system



The sybil identity can be generated by the malicious node, or stolen from an existing correct node



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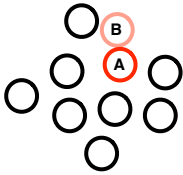
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Introduction – The Sybil Attack

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A Sybil attack happens when a malicious node participates with multiple identities in a system



○ Correct Node
 ○ Malicious Node
 ○ Sybil Identity

The sybil identity can be generated by the malicious node, or stolen from an existing correct node

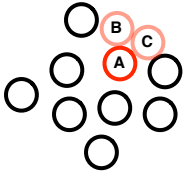

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Introduction – The Sybil Attack

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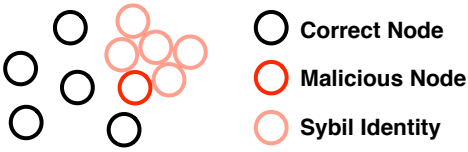
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Easily defeats quorum systems, or other voting schemes

Votes from Correct Nodes: 5
Votes from Malicious Node: 6



○ Correct Node
○ Malicious Node
○ Sybil Identity

In order to obtain a majority in a network with 5 correct nodes, a malicious node has to create 5 sybil identities

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Introduction – Resource Tests

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In resource testing we determine if a set of identities possess fewer aggregated resources than would be expected

- Computational Power
- Storage
- Network Bandwidth
- ...
- Radio Resource


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Introduction
➤ Radio Resource Tests
Analysis
Summary

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Radio Resource Tests


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Radio Resource Tests (RRTs) assume that each node has access to a single radio device, and builds upon the limitations of these devices

The first RRT was introduced by Newsome et. al
2004

We will call it **Sender Test**

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Radio Resource Tests – Sender Test technology
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Sender Test (SST)

- The **Sender Test** is based on the assumption that nodes cannot simultaneously transmit in more than one channel

The diagram illustrates the Sender Test (SST) process. On the left, a green circle (Challenger Node) sends packets labeled f_1 and f_2 to two black circles (Correct Nodes) on different channels. A blue arrow points to the right, where the green circle is shown sending a packet to both black circles, which are now emitting signal waves, indicating a failure of the test because simultaneous transmission is detected.

Correct Node
 Challenger Node

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Radio Resource Tests – Sender Test technology
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Sender Test (SST)

- The **Sender Test** is based on the assumption that nodes cannot simultaneously transmit in more than one channel

The diagram illustrates the Sender Test (SST) process. On the left, a green circle (Challenger Node) sends packets labeled f_1 and f_2 to a red circle (Malicious Node) and a pink circle (Sybil Identity) on different channels. A red arrow points to the right, where the green circle is shown sending a packet to both the red and pink circles, which are now emitting signal waves, indicating a failure of the test because simultaneous transmission is detected.

Challenger Node
 Malicious Node
 Sybil Identity

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Radio Resource Tests – Detection Probability



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The challenger is unable listen in more than one channel at the same time, so we repeat the test r times

- Denoting by h the number of simultaneously tested identities, and by p_d the probability of detection of a Sybil Identity in a test, we have

$$p_d = 1 - \left(1 - \frac{1}{h}\right)^r$$



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Radio Resource Tests – Contribution



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We introduce two new tests and an optimization for the **Sender Test**

- **Optimized Sender Test (oSST)**
- **Receiver Test (SRT)**
- **Collision Test (FCT)**




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Radio Resource Tests - Framework



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Each RRT is characterized by a set of parameters, $RRT(h, c, w)$

- h – Size of the set of simultaneously tested identities
- c – Number of challenger identities actively participating in the test
- w – Number of tester nodes that extract information from the test




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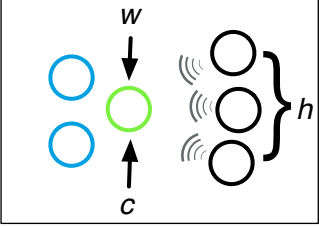
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Radio Resource Tests – Sender Test




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The **Sender Test** is a $RRT(K,1,1)$



- Tested Nodes
- Challenger Node
- Non-participating nodes

- h is limited by the number of available channels (K)
- c is one, since the challenger needs to assign in which channel identities transmit in
- w is one since only the challenger extracts information from the test




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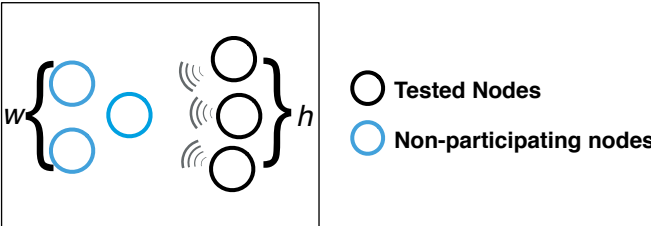
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Radio Resource Tests – Optimized Receiver Test




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The Optimized Sender Test is a $RRT(K,0,N-K)$




- h is limited by the number of available channels (K)
- c is zero, since the channels can be chosen deterministically
- w is $N - K$, since every node not participating in the test can extract information from it



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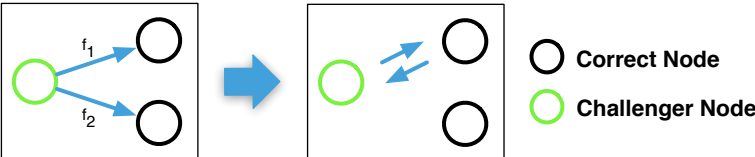
Radio Resource Tests – Receiver Test




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Receiver Test

- The Simultaneous Receiver Test is based on the assumption that nodes cannot simultaneously listen in more than one channel






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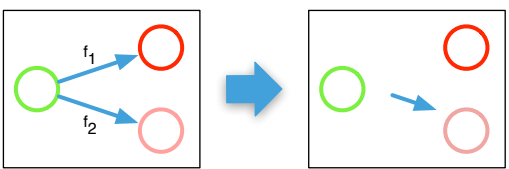
Radio Resource Tests – Receiver Test



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Receiver Test


- The Simultaneous Receiver Test is based on the assumption that nodes cannot simultaneously listen in more than one channel



○ Challenger Node

○ Malicious Node


○ Sybil Identity



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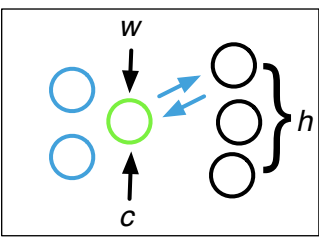
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Radio Resource Tests – Receiver Test



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The Receiver Test is a RRT(K,1,1)




○ Tested Nodes

○ Challenger Node

○ Non-participating nodes



- h is limited by the number of available channels K
- c is one, since the challenger needs to send a challenge on one of the channels
- w is one since only the challenger can extract information from the test (no other node knows the chosen channel)



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Road Map





Introduction

Radio Resource Tests

➤ **Analysis**



Summary



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Radio Resource Tests - Analysis

We compared the tests using the following metrics

- Vulnerability to collusion
- Message cost
- Resource consumption
- Synchronization requirements
- Number of messages needed to achieve a desired probability of detection



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Analysis – Optimized Sender Test – Vulnerability to collusion

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Vulnerability to collusion

$h > m$

$h \leq m$

- Malicious Nodes
- Sybil Identities
- Non-participating nodes

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Analysis – Optimized Sender Test – Vulnerability to collusion

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Vulnerability to collusion

$h > m$

$h \leq m$

- Malicious Nodes
- Sybil Identities
- Non-participating nodes

The **Optimized Sender Test** Handles at most $h - 1$ colluding malicious nodes (m)

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Analysis – Optimized Sender Test – Message Cost

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Message Cost

○ Tested Nodes
○ Non-participating nodes

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Analysis – Optimized Sender Test – Message Cost

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Message Cost

○ Tested Nodes
○ Non-participating nodes

In the **Optimized Sender Test**, tested nodes send a total of h messages per round

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Analysis – Optimized Sender Test – Resource Consumption

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Resource Consumption (DoS Opportunity)

Malicious Tester

○ Malicious Nodes
○ Tested Nodes
○ Non-participating nodes

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Analysis – Optimized Sender Test – Resource Consumption

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Resource Consumption (DoS Opportunity)


Malicious Tester

○ Malicious Nodes
○ Tested Nodes
○ Non-participating nodes

In the **Optimized Sender Test**, when there is a malicious tester, $\Delta = rh - 1$.

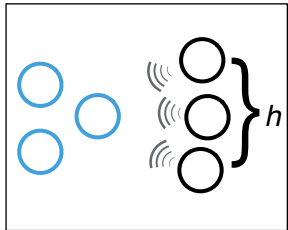
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**Analysis – Optimized Sender Test –
Synchronization Requirements**




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Synchronization Requirements



○ Tested Nodes


○ Non-participating nodes



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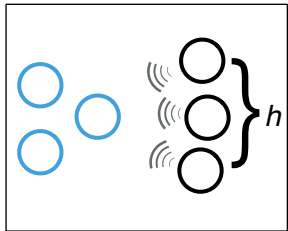
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**Analysis – Optimized Sender Test –
Synchronization Requirements**



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Synchronization Requirements



○ Tested Nodes

○ Non-participating nodes

In the **Optimized Sender Test**, tested nodes are required
 to transmit simultaneously



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Analysis – Comparison Table

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Metric	Tests		
	Optimized Sender Test	Receiver Test	Collision Test
Collusion	$h - 1$	$h - 1$	1
Message Cost	h	2	2
Resource Consumption (malicious tester)	$rh - 1$	0	r
Synchronization	Strong	Strong	Weak

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Analysis – Comparison Table

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Metric	Tests		
	Optimized Sender Test	Receiver Test	Collision Test
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Analysis – Testing a Population of Nodes

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Testing a group of nodes

○ Tested Nodes
○ Tester Nodes

Every node in the one-hop neighborhood has to test every other node

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Analysis – Testing a Population of Nodes

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Analysis – Testing a Population of Nodes

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Testing a group of nodes

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Analysis – Testing a Population of Nodes

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Testing a group of nodes


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Every node in the one-hop neighborhood has to test every other node

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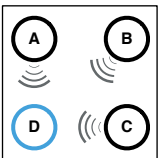
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Analysis – Testing a Population of Nodes




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Testing a group of nodes



 **Tested Nodes**

 **Tester Nodes**

Every node in the one-hop neighborhood has to test every other node




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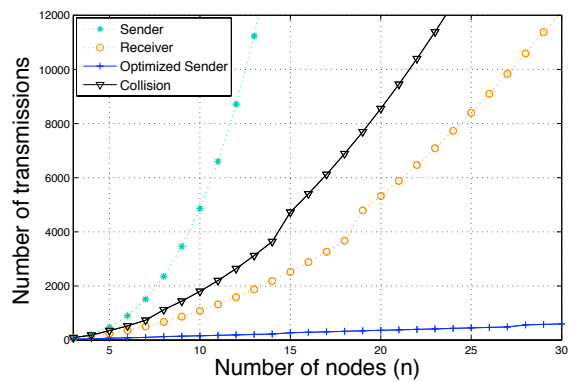
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Radio Resource Tests - Performance




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Performance in number of messages



Number of nodes (n)	Sender	Receiver	Optimized Sender	Collision
5	~100	~100	~100	~100
10	~400	~400	~100	~400
15	~900	~900	~100	~900
20	~1600	~1600	~100	~1600
25	~2500	~2500	~100	~2500
30	~3600	~3600	~100	~3600

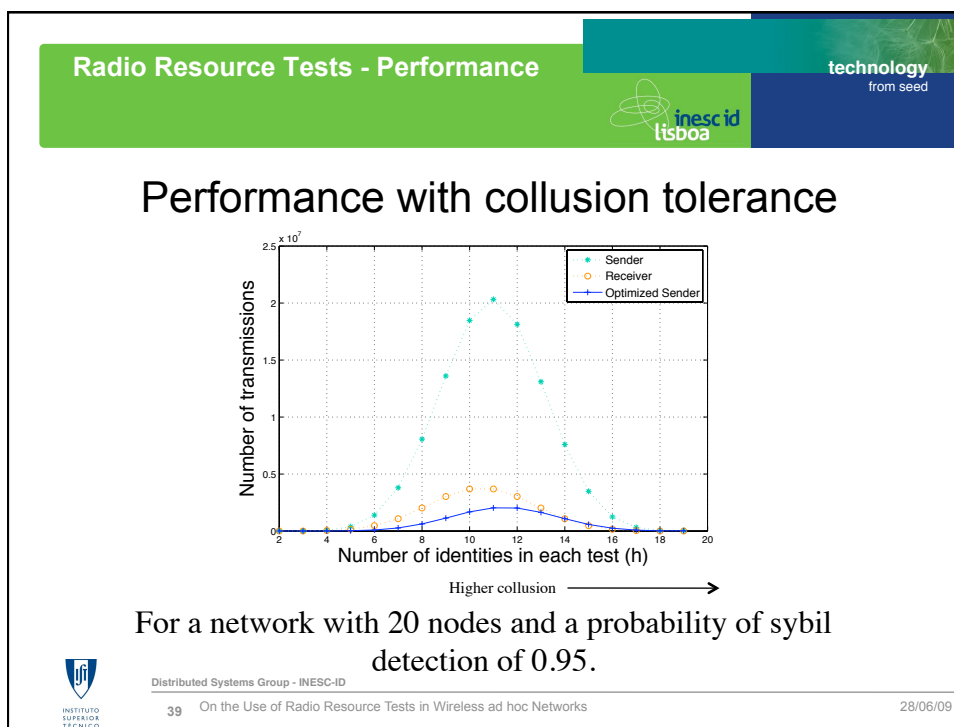
For a probability of sybil detection of 0.95.





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Radio Resource Tests – Application Scenarios

Application Scenarios



Test	Best Performance Context
Optimized Sender Test	No DoS threat
Receiver Test	High collusion and/or DoS threat
Collision Test	One Channel



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Road Map





Introduction

Radio Resource Tests

Analysis



➤ **Summary**




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Summary

- Radio Resource Tests are a viable mechanism for detecting sybil identities in Wireless ad hoc Networks
- We presented two new RRTs and an optimization to an existing RRT
- We presented a framework to compare the RRTs
- We analyzed all the tests both in isolation, and when used to test a one-hop neighborhood.
- We have shown that each test is best adapted to a specific scenario, which we described.



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