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

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Road Map

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- Introduction
- Radio Resource Tests
- Analysis
- Summary

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

Introduction – The Sybil Attack

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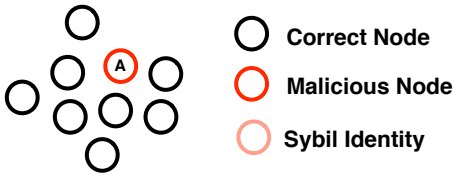
A Sybil attack happens when a malicious node participates with multiple identities in a system



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

Introduction – The Sybil Attack

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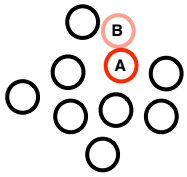

Correct Node

Malicious Node

Sybil Identity

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

Introduction – The Sybil Attack

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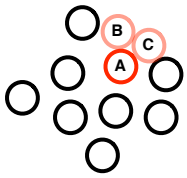

Correct Node

Malicious Node

Sybil Identity

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

Introduction – The Sybil Attack

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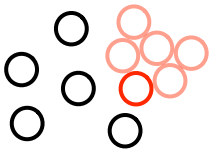
Easily defeats quorum systems, or other voting schemes

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

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

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

Radio Resource Tests – Sender Test

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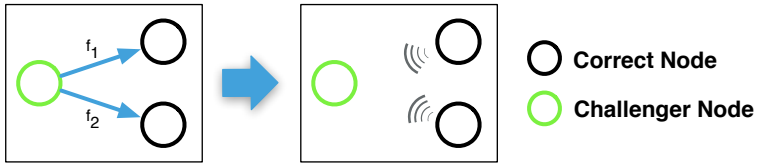
Sender Test (SST)

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



Radio Resource Tests – Sender Test

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Sender Test (SST)

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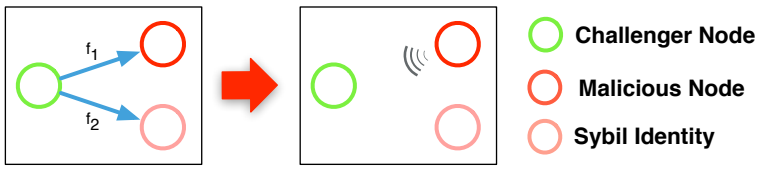

Radio Resource Tests – Detection Probability

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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

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

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)

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

Radio Resource Tests – Sender Test

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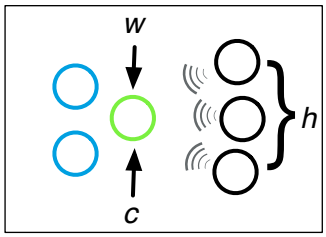
The Sender Test is a RRT(K,1,1)



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

Radio Resource Tests – Optimized Receiver Test

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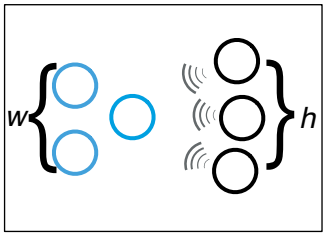
The Optimized Sender Test is a RRT(K,0,N-K)



Tested Nodes

Non-participating nodes

- *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

Radio Resource Tests – Receiver Test

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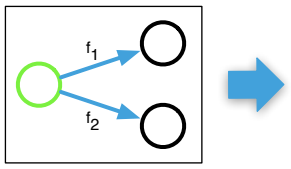
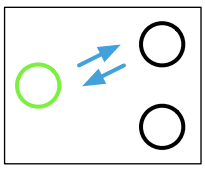
Receiver Test

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





Correct Node

Challenger Node

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Receiver Test

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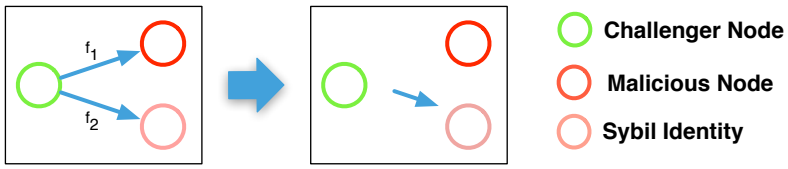

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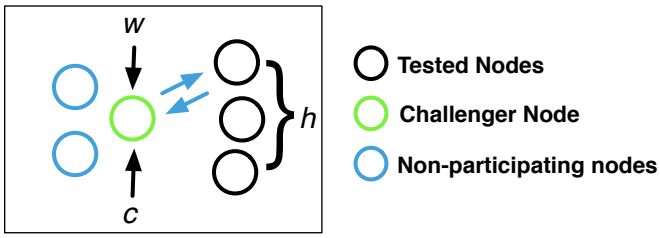
The Receiver Test is a RRT(K,1,1)



- *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)

Road Map

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Introduction
Radio Resource Tests
➢ Analysis
Summary

Radio Resource Tests - Analysis

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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

Analysis – Optimized Sender Test – Vulnerability to collusion

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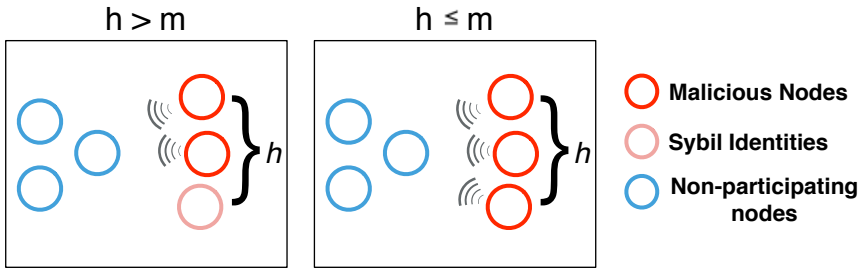
Vulnerability to collusion



Analysis – Optimized Sender Test – Vulnerability to collusion

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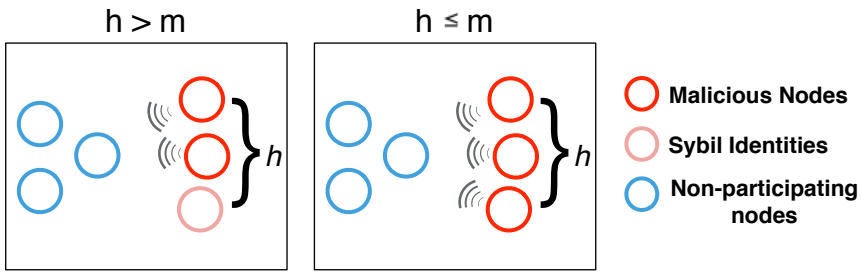
Vulnerability to collusion



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

Analysis – Optimized Sender Test – Message Cost

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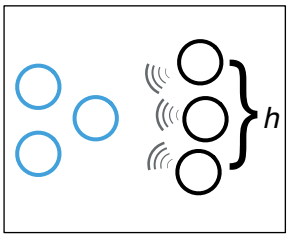
Message Cost



Tested Nodes

Non-participating nodes

Analysis – Optimized Sender Test – Message Cost

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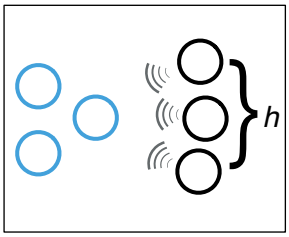
Message Cost



Tested Nodes

Non-participating nodes

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

Analysis – Optimized Sender Test – Resource Consumption

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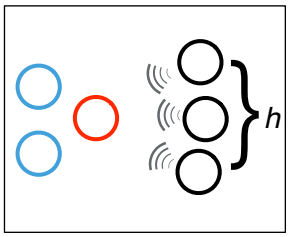
Resource Consumption (DoS Opportunity)

Malicious Tester



- Malicious Nodes
- Tested Nodes
- Non-participating nodes

Analysis – Optimized Sender Test – Resource Consumption

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Resource Consumption (DoS Opportunity)

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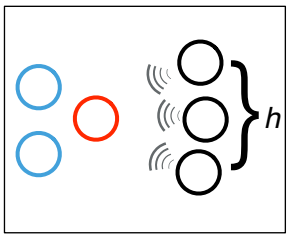

- Malicious Nodes
- Tested Nodes
- Non-participating nodes

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

Analysis – Optimized Sender Test – Synchronization Requirements

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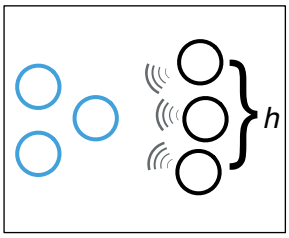
Synchronization Requirements



Tested Nodes

Non-participating nodes

Analysis – Optimized Sender Test – Synchronization Requirements

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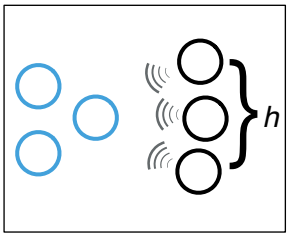
Synchronization Requirements



Tested Nodes

Non-participating nodes

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

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

Analysis – Comparison Table

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Metric	Tests		
	Optimized Sender Test	Receiver Test	Collision Test
Collusion	h - 1	h - 1	1
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Synchronization	Strong	Strong	Weak

Analysis – Testing a Population of Nodes

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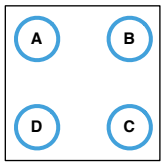
Testing a group of nodes



Tested Nodes

Tester Nodes

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

Analysis – Testing a Population of Nodes

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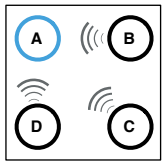
Testing a group of nodes



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Analysis – Testing a Population of Nodes

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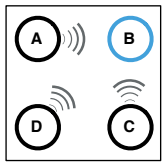

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Analysis – Testing a Population of Nodes

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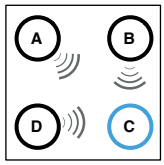

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Analysis – Testing a Population of Nodes

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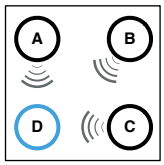
Testing a group of nodes



Tested Nodes

Tester Nodes

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Radio Resource Tests - Performance

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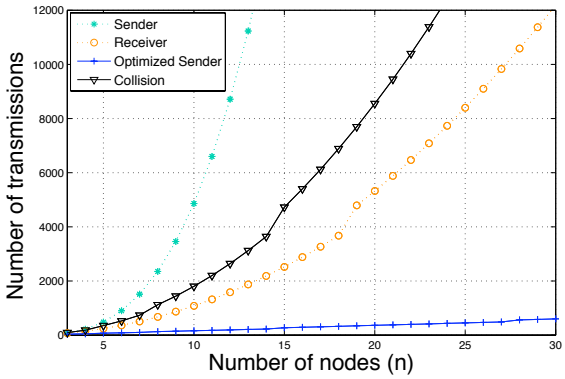
Performance in number of messages



For a probability of sybil detection of 0.95.

Radio Resource Tests - Performance

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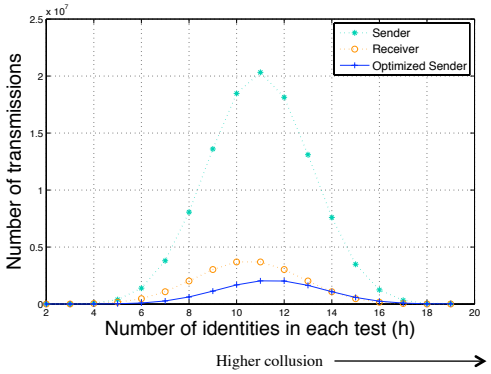
Performance with collusion tolerance



For a network with 20 nodes and a probability of sybil detection of 0.95.

Radio Resource Tests – Application Scenarios

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Application Scenarios

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

Road Map

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Introduction
Radio Resource Tests
Analysis
➢ Summary

Summary

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- 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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