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Editors

Computer Networks & Communications (NetCom)

Proceedings of the Fourth International
Conference on Networks & Communications

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Preface

The Fourth International Conference on Networks and Communications (NETCOM 2012) has been held in Chennai, India during December 22–24, 2012. The conference is proved to stimulate researchers from different parts of the world to exchange their ideas in the field of computer networks and data communications including various applications of these. The goal of this conference is to bring together researchers and practitioners from academia and industry to focus on understanding the domain of computer networking and communication technology toward establishing new collaborations in these areas. Authors invited to contribute by submitting original research articles that illustrate research results, projects, survey works, and industrial experiences describing significant advances in the relevant areas.

The conference organizing committee of the NETCOM 2012 took great initiative and interest in circulating the Call for Papers (CFP) for the conference. This effort resulted in a large number of submissions from the researchers of the leading International Universities and Institutes of 32 countries across the world. All the submissions underwent a tough and careful peer-review process with voluntary participation of the committee members and external expert reviewers. The papers had been reviewed based on the novelty of the contributions, technical content, organization, and clarity in presentation. The entire process of initial paper submission, review, and acceptance processes was done electronically. All these efforts undertaken by the Organizing and Technical Committees led to an exciting, rich, and a high-quality technical conference program. The NETCOM 2012 conference featured high-impact presentations for all attendees to enjoy, appreciate, and expand their expertise in the latest developments in Networks and Communications research.

The Technical Program Committee for the conference has selected only 84 papers for publication out of a total 469 number of submissions. The conference proceeding has been organized as a collection of papers presented in the order in which the papers appear in the final technical program for NETCOM 2012. We would like to take this opportunity to thank the General Chairs of NETCOM 2012. We are thankful to all the members of the Technical Program Committee and the

external reviewers for their excellent and tireless work. We would also thank Springer for the strong support and the authors who contributed to the success of the conference. Last, but not the least, on behalf of Steering Committee of NETCOM 2012, we sincerely wish that all attendees had been benefited scientifically from the conference. Indeed, we would consider ourselves worth of organizing such an event to offer a platform for all of you if some of tomorrow's works of excellence find its roots initiated from the podium of NETCOM 2012.

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Contents

Part I The Fourth International Conference on Networks & Communications (NETCOM-2012): Adhoc and Sensor Networks

Perspectives of Sybil Attack in Routing Protocols of Mobile Ad Hoc Network	3
Manu Sood and Amol Vasudeva	
A Jini Based Implementation for Best Leader Node Selection in MANETs	15
Monideepa Roy, Pushpendu Kar and Nandini Mukherjee	
A Novel Methodology for Securing Ad Hoc Network by Friendly Group Model	23
Md. Amir Khusru Akhtar and G. Sahoo	
Energy Efficient Medium Access Protocol for Clustered Wireless Sensor Networks	37
K. N. Shreenath and K. G. Srinivasa	
A Design Mode of Streaming Media Transmission and Access in Wireless Video Sensor Network	47
Mengxi Xu, Chenrong Huang, Shengnan Zheng and Jianqiang Shi	
PSO-PAC: An Intelligent Clustering Mechanism in Ad Hoc Network	55
S. Thirumurugan and E. George Dharma Prakash Raj	
SEMSuS: Semantic Middleware for Dynamic Service-Oriented Sensor Network.	63
V. Sangeetha and L. Jagajeevan Rao	

CO₂ Gas Sensor Using Resonant Frequency Changes in Micro-Cantilever	75
S. Subhashini and A. Vimala Juliet	
 Part II The Fourth International Conference on Networks & Communications (NETCOM-2012): Heterogeneous Wireless, WLAN and Mobile Networks	
A Mechanism for Enhanced Performance of Chord DHT in Mobile Environment	83
Vu Thanh Vinh and Nguyen Chan Hung	
A Hybrid Model of CLMS and ACLMS Algorithms for Smart Antennas	93
Y. Rama Krishna, P. E. S. N. Krishna Prasad, P. V. Subbaiah and B. Prabhakara Rao	
Novel Protection from Internal Attacks in Wireless Sensor Networks	105
Xu Huang, Muhammad Ahmed and Dharmendra Sharma	
Channel-Usage Model in Underlay Cognitive Radio Networks	115
Sanjib K. Deka and Nityanada Sarma	
Supporting LTE Networks in Heterogeneous Environment Using the Y-Comm Framework	125
Mahdi Aiash, Glenford Mapp, Aboubaker Lasebae and Ameer Al-Nemrat	
A Call Admission Control Scheme for Cellular Network to Handle Sudden Influx in a Confined Area	137
Bhattacharya Adrija and Choudhury Sankhayan	
Distributed Joint Optimal Network Scheduling and Controller Design for Wireless Networks	147
Hao Xu and S. Jagannathan	
On the Estimation Capacity of Equal Gain Diversity Scheme Under Multi-path Fading Channel	163
Moses Ekpenyong, Joseph Isabona and Imeh Umoren	

Low Overhead Time Coordinated Checkpointing Algorithm for Mobile Distributed Systems 173
 Jangra Surender, Sejwal Arvind, Kumar Anil and Sangwan Yashwant

Part III The Fourth International Conference on Networks & Communications (NETCOM-2012): Measurement and Performance Analysis

Performance Evaluation of TCP NewVegas and TCP Newreno on Burstification in an OBS Network. 185
 K. Ratna Pavani and N. Sreenath

Performance Enhancement Through Optimization in FPGA Synthesis: Constraint Specific Approach 195
 R. Uma and P. Dhavachelvan

Performance Optimization of Vehicular Ad Hoc Network (VANET) Using Clustering Approach 205
 Ankita Anand and Parminder Singh

Performance Evaluation of TCP Congestion Control Variants Using Ad Hoc On-Demand Distance Vector Routing. 213
 Mayank Kumar Goyal, Punit Gupta and Vinita Chauhan

Performance Analysis of Dynamic Source Routing for Ad-Hoc Networks Using Active Packet 221
 Manish Bhardwaj, Naresh Sharma and Ruchika Saini

Overhead Analysis of AODV, TORA and AOMDV in MANET Using Various Energy Models 231
 Manish Bhardwaj, Naresh Sharma and Monika Johri

Part IV The Fourth International Conference on Networks & Communications (NETCOM-2012): Network Architectures, Protocols and Routin0067

Low Power and High Speed Adders in Modified Gated Diffusion Input Technique 243
 R. Uma and P. Dhavachelvan

Guided Local Search for Optimal GPON/FTTP Network Design 255
 Ali Rais Shaghghi, Tim Glover, Michael Kampouridis
 and Edward Tsang

**Image Segmentation Using Variable Kernel Fuzzy C Means
 (VKFCM) Clustering on Modified Level Set Method** 265
 Tara Saikumar, Khaja FasiUddin, B. Venkata Reddy
 and Md. Ameen Uddin

**Comparison of SPIHT, Classical and Adaptive Lifting Scheme
 for Compression of Satellite Imageries** 275
 K. Nagamani, A. G. Ananth and K. V. S. Ananda Babu

**A Gene Expression Based Quality of Service Aware Routing
 Protocol for Mobile Ad Hoc Networks** 283
 Yeshavanta Kubusada, Giridhar Mohan, Kiran Manjappa
 and G. Ram Mohana Reddy

**User Behavior and Capability Based Access Control Model
 and Architecture** 291
 Meriem Zerkouk, Abdallah Mhamed and Belhadri Messabih

**Congestion Adaptive Most Favorable Control Routing
 in Ad Hoc Networks** 301
 S. Subburam and P. Sheik Abdul Khader

**An Improved Blind Channel Estimation Based on Subspace
 Approach for OFDM Systems Under Fast Time
 Varying Conditions** 311
 Zaier Aida and Ridha Bouallegue

**Adaptive Control and Synchronization Design
 for the Lu-Xiao Chaotic System** 319
 Vaidyanathan Sundarapandian

**Part V The Fourth International Conference on Networks
 & Communications (NETCOM-2012):
 Network Operations and Management**

**Secure Patient Monitoring and Self-management Using
 Brain Expression Interpreter** 331
 Suleyman Kondakci and Dilek Doruk

Coverage and Connectivity Guaranteed Deterministic Deployment Pattern for WSN 341
 R. Ramalakshmi and S. Ramalakshmi

Hybrid Deployment Schemes for Wireless Sensor Networks 349
 G. Sanjiv Rao and V. Vallikumari

Adaptive Optimal Distributed Power Allocation for Enhanced Cognitive Radio Network in the Presence of Channel Uncertainties 359
 Hao Xu and S. Jagannathan

Secure Real Time Remote Video Monitoring System 371
 Deepti C. Gavankar and Madhumita Chatterjee

Fully Self-organized Key Management Scheme in MANET and Its Applications 381
 Fuyou Miao, Wenjing Ruan, Xianchang Du and Suwan Wang

A Hierarchical Color Net Model for Smart Grid Security Monitoring 393
 Debraj Ghosh and Nabendu Chaki

Part VI The Fourth International Conference on Networks & Communications (NETCOM- 2012): Network Security, Trust and Privacy

A Comprehensive Study on Two-factor Authentication with One Time Passwords 405
 Kumar Abhishek, Sahana Roshan, Abhay Kumar and Rajeev Ranjan

ITRANS Encoded Marathi Literature Document Relevance Ranking for Natural Language Flexible Queries. 417
 V. M. Pathak and M. R. Joshi

AB-OR: Improving the Efficiency in Onion Routing Using Attribute Based Cryptography. 425
 Nishant Doshi and Devesh Jinwala

Pasic: A Novel Approach for Page-Wise Web Application Security. . . 433
 Angamuthu Maheswaran and Rajaram Kanchana

Cryptanalysis of Lo et al.’s Password Based Authentication Scheme 445
Nishant Doshi and Bhavesh Patel

Intrusion Detection in Zero Knowledge System Using Model Checking Approach 453
Teslin Jacob, Mithun Raman and Sanjay Singh

Detecting Malicious Users in P2P Streaming Systems by Using Feedback Correlations 467
Feng-Li Zhang, Yang Bai, Jie Hou and Yuan-Wei Tan

An Efficient Dual Text Steganographic Approach: Hiding Data in a List of Words. 477
Monika Agarwal

Secure Cryptosystem with Blind Authentication 489
Suhas J. Lawand and Madhumita Chatterjee

An Effective Technique for Intrusion Detection Using Neuro-Fuzzy and Radial SVM Classifier 499
A. M. Chandrasekhar and K. Raghuv eer

A Novel Octuple Images Encryption Algorithm Using Chaos in Wavelet Domain 509
Musheer Ahmad, Bashir Alam, Arpit Jain and Vipul Khare

Part VII Workshops: The Fourth International Workshop on Network and Communications Security (NCS 2012)

A Strong PVSS Scheme 521
Fuyou Miao, Xianchang Du, Wenjing Ruan and Suwan Wang

Secure Cosine Similarity Computation with Malicious Adversaries . . . 529
Dexin Yang, Baolin Xu, Bo Yang and Jianping Wang

Test Suite for Intrusion Detection by Layered Conditional Random Fields Using Mobile Phones 537
M. Arpitha, V. Geetha, K. H. Gowranga and R. Bhakthavathsalam

An Efficient Microaggregation Method for Protecting Mixed Data . . . 551
S. K. Chettri and B. Borah

Plus/Delta (+/Δ) Evaluation to Help Organizations Deliver Projects Effectively 563
 A. Pathanjali Sastri and K. Nageswara Rao

A Secure Routing Protocol for MANETs Against Byzantine Attacks 571
 Gagan Singla and Pallavi Kaliyar

Analysis of Different Mobility Models for Ad Hoc On-Demand Distance Vector Routing Protocol and Dynamic Source Routing Protocol 579
 Gaurika Talwar, Hemika Narang, Kavita Pandey and Pakhi Singhal

NIZKPDS to Achieve Non-repudiation 589
 S. Samundeeswari and V. S. Shankar Sriram

An Integrated Solution for Both Monitoring and Controlling for Automization Using Wireless Sensor Networks: A Case Study. 599
 M. Gnana Seelan and Ch. A. S. Murty

A Secure Image Steganography Technique to Hide Multiple Secret Images 613
 S. Hemalatha, U. Dinesh Acharya, A. Renuka and Priya R. Kamath

Source Code Analysis of a Connection-Oriented File Reader Server Socket Program in Java and Removal of the Security Vulnerabilities 621
 N. Meghanathan

Document Library System Using RDF Based Inferences 631
 Archana P. Kumar, Kumar Abhishek and Abhay Kumar

Part VIII Workshops: The Fourth International Workshop on Wireless and Mobile Networks (WiMoNe-2012)

Spread and Erase: Efficient Routing Algorithm Based on Anti-message Info Relay Hubs for Delay Tolerant Networks 643
 Shikha Jain and Sandhya Aneja

Novel Architecture of Adaptive and Optimized Policy Based Handover in MANET 653
 Nidhi Parashar and A. K. Vatsa

Trusted Control Information in the Application of Cold Chain Logistics 665
 Li Li, Jia Yingqian, Zhao cuijian and Wu hao

PHY Layer Considerations for Real Time Multimedia Signal Transmission in Wireless Medium 675
 S. M. Koli, R. G. Purandare, S. P. Kshirsagar and V. V. Gohokar

Approximate Minimum Spanning Tree for Points Moving in a Euclidean Two-Dimensions Plane 691
 Anil Kumar Sahu, Chintan Mandal and Suneeta Agarwal

Low Complexity Speech Enhancement Algorithm for Improved Perception in Mobile Devices 699
 B. S. Premananda and B. V. Uma

Prolonging the Lifetime of Wireless Sensor Network by Exponential Node Distribution and Ant-Colony Optimization Routing 709
 Zaheeruddin, Aruna Pathak and Manoj Kumar Tiwari

Multimedia Traffic Over MANETs: Evaluation and Performance Analysis 719
 Sunil and Naveen

Web Accessibility: Designing and Testing of Web Based Application for Persons with Disabilities. 729
 Kalpana Johari and Arvinder Kaur

CBADE: Hybrid Approach for Duplication Detection and Elimination 737
 A. Anny Leema, P. Sudhakar and M. Hemalatha

Part IX Workshops: Fourth Workshop on Applications of Graph Theory in Wireless Ad hoc Networks and Sensor Networks (GRAPH-HOC - 2012)

Energy Aware Multipath Routing Protocol for Wireless Sensor Networks 753
 Suraj Sharma, Pratik Agarwal and Sanjay Kumar Jena

Virtual Classroom for E: Education in Rural Areas 761
 Vimal Upadhyay, Mukesh Chand and Piyush Chaudhary

Unsupervised Methods on Image Database Using Cluster Mean Average Methods for Image Searching 777
 R. Venkata Ramana Chary, K. V. N. Sunitha and D. Rajya Lakshmi

Impact of Fix Cluster Head Selection (FCHS) Routing Protocol for Wireless Sensors Network 789
 Priyanka Chugh Shivanka and Ashwani Kumar

Part X Workshops: The Fourth International Workshop on Ad Hoc and Ubiquitous Computing (AUC- 2012)

Ontology Oriented Approach to Service Selection and Invocation in Complex Context Analysis 799
 Slawomir Nasiadka

Compression of ECG Signals Using a Novel Discrete Wavelet Transform Algorithm for Dynamic Arrhythmia Database. 809
 Sangeeta Gupta and Sujoy Bhattacharya

Performance Analysis of ETX and ETT Routing Metrics Over AODV Routing Protocol in WMNs 817
 Satish Hatti and M. B. Kamakshi

Optimized CPU Frequency Scaling on Android Devices Based on Foreground Running Application 827
 Tanuj Mittal, Lokesh Singhal and Divyashikha Sethia

Message Efficient Ring Leader Election in Distributed Systems. 835
 P. Beulah Soundarabai, J. Thriveni, H. C. Manjunatha, K. R. Venugopal and L. M. Patnaik

RAW: A Novel Reconfigurable Architecture Design Using Wireless for Future Generation Supercomputers 845
 S. Vignesh, G. Vijayraghavan and S. Srinath

Interference Management Analysis of Double-ABBA and ABBA Quasi-Orthogonal Space Time Code 855
 Mohammad Abu Hanif and Moon Ho Lee

Index 863

Part I
The Fourth International Conference
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(NETCOM-2012): Adhoc and
Sensor Networks

Perspectives of Sybil Attack in Routing Protocols of Mobile Ad Hoc Network

Manu Sood and Amol Vasudeva

Abstract It is cumbersome to achieve the security in a mobile ad hoc network due to its open nature, dynamically changing topology, lack of infrastructure and central management. A particular harmful attack that takes the advantage of these characteristics is the Sybil attack, in which a malicious node illegitimately claims multiple identities. Two routing mechanisms vulnerable to the Sybil attack in the mobile ad hoc networks are multi-path routing and geographic routing. In addition to these routing protocols, we show in this paper that the Sybil attack can also disrupt the head selection mechanism of various cluster-based routing protocols such as lowest id, highest node degree and mobility based clustering. To achieve this, we illustrate to have introduced a category of Sybil attack in which the malicious node varies its transmission power to create a number of virtual illegitimate nodes called Sybil Nodes, for the purpose of communication with legitimate nodes of the MANETs.

Keywords Mobile ad hoc network · Sybil attack · Malicious node · Sybil node · Network security · Routing protocol

1 Introduction

Security is an important concern in the Mobile Ad hoc Networks (MANETs). However, the characteristics of MANETs pose both challenges and opportunities in achieving the security goals, such as confidentiality, authentication, integrity,

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availability, access control and non-repudiation [1]. There are a wide variety of attacks that target the weakness of MANET routing protocols. Most sophisticated and subtle routing attacks have been identified in some recently published papers such as Blackhole [2], Rushing [3], wormhole [4] and Sybil attack [5] etc. A Sybil attack is an attack [5], in which a malicious node illegally claims multiple identities by impersonating other nodes or by claiming fictitious identities. Sybil attacks are also capable of disrupting the routing mechanisms in mobile ad hoc networks. Karlof and Wagner have shown in [6] that multi-path routing and geographical routing schemes are affected by this attack. In case of multi-path routing a set of supposedly disjoint paths can all be passing through the same malicious node, which is using several Sybil identities. Also in location based routing a malicious node can present multiple Sybil nodes with different positions to its neighbors. Therefore, a legitimate node may choose any of the Sybil nodes while forwarding the packet on the basis of nearest location to the destination node; but in reality it will be passing the packets through the malicious node.

In addition to these routing protocols, we have shown in this paper that the Sybil attack can also disrupt the head selection mechanism of various cluster-based routing protocols such as lowest ID [7], highest node degree [8] and mobility based clustering [9]. To the best of our knowledge, this is for the first time that the impact of Sybil attack has been shown in these cluster based routing algorithms. The rest of this paper is organized as follows. Section 2 describes the Sybil attack in details. Section 3 describes the following routing protocols: Split Multi-path Routing (SMR) [10], Greedy Perimeter Stateless Routing (GPSR) [11] and various cluster based routing protocols along with the effect of Sybil attack on these protocols, respectively. Finally, the Sect. 4 concludes the paper.

2 Sybil Attack

Sybil attack was first introduced by J. R. Douceur. According to Douceur, the Sybil attack is an attack by which a single entity can control a substantial fraction of the system by presenting multiple identities [5]. The Sybil attack can occur in a distributed system that operates without a central authority to verify the identities of each communicating entity [12].

In a Mobile Ad hoc Network, the only way for an entity to detect the presence of other entities is by sending and receiving the messages over a shared broadcast communication channel. By taking the advantage of this feature, a malicious node can send messages with multiple fake identities. The node spoofing the identities of the nodes is called malicious node/Sybil attacker, and the nodes whose identities are spoofed are called Sybil nodes. Figure 1 represents a malicious node S along with its four Sybil nodes (S_1 , S_2 , S_3 and S_4). If this malicious node communicates with any legitimate node by presenting all its identities, the legitimate node will have illusion that it has communicated with five different nodes. But in actual, there exists only one physical node with multiple different IDs. If a single malicious node is able to

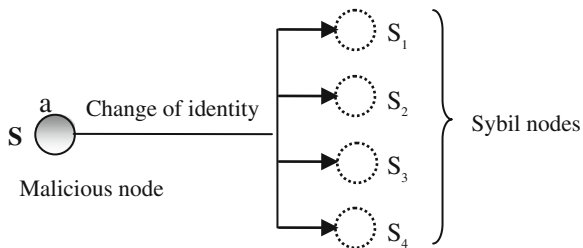


Fig. 1 A Sybil attacker with multiple IDs

convince its neighbors by presenting multiple identities, it will have control over the substantial portion of the network and can adversely affect the functioning of the network. According to Newsome [12], the mechanisms that are affected by the Sybil attack are: Data Aggregation, Fair Resource Allocation, Voting and Misbehavior Detection etc. Karlof and Wagner have shown in [6] that Sybil attack can also disrupt the functioning of certain routing protocols in MANETs such as multi-path routing protocols [10, 13, 14] and geographic based routing protocols [11, 15, 16].

The launching of the Sybil attack can be represented using three dimensions: Communication, Participation and Identity [12]. Newsome et al. state that there are two ways of communication: Direct and Indirect [12]. In a direct communication, as the name implies, the malicious node allows its Sybil nodes to communicate directly with the legitimate nodes. In case of indirect communication, the malicious node does not allow its Sybil nodes to communicate directly with the legitimate nodes. However, the authors are of the opinion that the title ‘Establishment of the Connection’ would have been more appropriate instead of the title ‘Communication’. Participation is concerned about the participation of Sybil nodes in the communication with legitimate nodes in the network. These nodes can participate simultaneously or non-simultaneously. There are two methods by which a Sybil node can get the identity: In the first method a Sybil node can steal the identity of a legitimate node by impersonating it. The second method involves the fabrication of a fresh fake identity.

3 Sybil Attack in MANET Routing Protocols

In this section, we have illustrated the impact of Sybil attack on Split Multi-path Routing (SMR) and Greedy Perimeter Stateless Routing (GPSR). In addition to these routing protocols, we have shown that the Sybil attack can also disrupt the different forms of Cluster Based Routing Protocols such as Lowest ID Clustering, Highest Node Degree Clustering and Mobility based Clustering.

3.1 Sybil Attack in Split Multi-Path Routing (SMR)

Split Multi-path Routing (SMR) [10], one of the multi-path routing protocols based on Dynamic Source Routing (DSR) [17], establishes and utilizes multiple maximally disjoint paths. Unlike DSR, the intermediate nodes in SMR do not respond to route requests, in order to obtain maximal node disjoint paths. Intermediate nodes forward the first RREQ they receive and instead of dropping all the duplicate RREQ packets, rebroadcast those duplicate packets that are being received through a different incoming link and whose hop count is not greater than the previously received RREQs. When the destination node receives the first RREQ, it responds with RREP to the source node and then waits for certain duration of time, to receive additional requests. The destination node then selects the route that is maximally disjoint to the route that is already replied. Consider Fig. 2a, where the source node S floods the RREQ packets to find an optimal route to the destination node D. The intermediate nodes forward the duplicate RREQ packets that traversed through a different incoming link than the link from which the first RREQ is received, and whose hop count is not greater than that of the first received RREQ. Now assume that a Sybil attacker node M has established itself in the network with two fake IDs i.e. X and Y. Thus, in this case the packets are being forwarded through a single physical node i.e. M. When

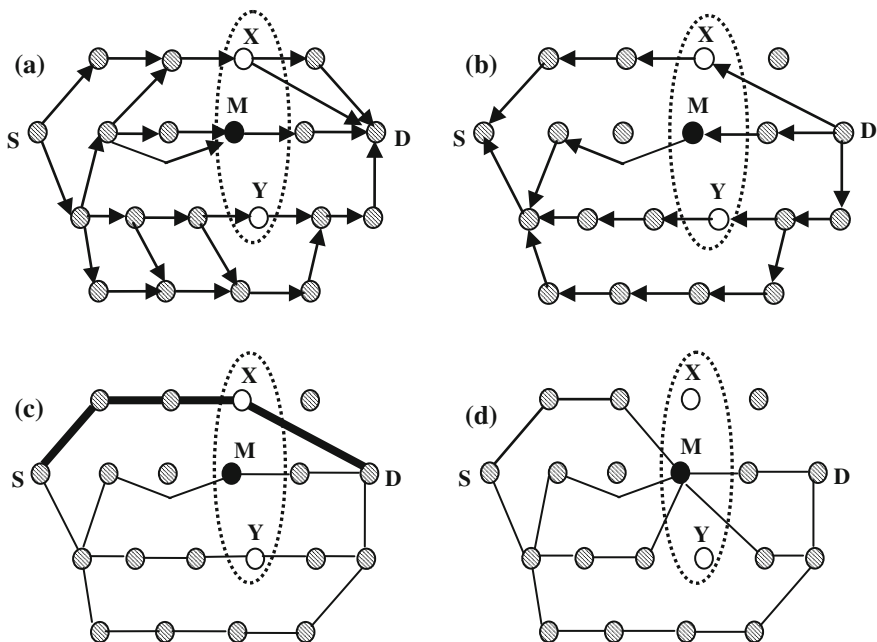


Fig. 2 a Flooding of RREQ packet from S to D. b RREP packets from D to S. c Selections of multiple disjoint paths. d Routes passing through the same node M. S-Source Node, D-Destination Node, M-Malicious Node, X, Y-Sybil Nodes

the RREQ packets have started to arrive at the destination node, it starts to send the RREP packets back towards the source node (Fig. 2b).

The path followed by each RREP packets is same as that of their corresponding RREQ packets. After receiving all the RREP packets the source node S makes the entry in its routing table. It then chooses the route with minimum hop count of 4 as shown in Fig. 2c by a thick line. But in reality, three routes are being passed through the same malicious node M and the Fig. 2d depicts that the routing mechanism has been disrupted, effectively.

3.2 Sybil Attack in GPSR Routing

The Greedy Perimeter Stateless Routing (GPSR) algorithm [11] works in two modes: greedy forwarding and perimeter forwarding. The algorithm starts forwarding with the greedy mode, by default. In greedy forwarding the source node looks for its neighbor that is closest to the destination and forwards the packet to that node. This process is repeated for the next node also and so on. Consider a MANET topology with 11 nodes as shown in the Fig. 3. Assume that the node C is a malicious node or Sybil attacker who somehow has succeeded to enter into the network. The actual position of this node is (7, 9). This node has presented two fake IDs i.e. the Sybil nodes D, E with their locations as (4, 11) and (11, 8), respectively. The node communicates with the other neighbors in its region by providing all the three locations (one actual and two fake). Thus, an adversary may claim to be present at more than one location for its neighbors by sending multiple HELLO messages, each time with different location information. Now suppose that the node A wants to send the packet to the destination I and to find the route it follows the greedy forwarding. A's radio range is denoted by the dotted circle about A and the arc with the radius equal to the distance between A and I is shown as arc about I. The node A forwards the packet to the Sybil node E, as it finds that the distance between E and I is less than between E and any of the A's other neighbors, according to the location information available in its Table 1. But in fact, node A has forwarded the packet to node C whose location is (7, 9) having a distance greater than the distance from node D (8, 2). Therefore, the routing scheme has been disrupted in the MANET with the entry of Sybil attacker.

3.3 Sybil Attack in Cluster-Based Routing Protocols

A Sybil attacker can also send the messages by varying its transmission power for all of its identities. The advantage of varying the transmission power for all the Sybil nodes is that the received signal strength at the receiving node with respect to these Sybil nodes will also be different. We have used the feature of variable transmission power to show that the Sybil attack can also disrupt various cluster based routing schemes such as lowest ID, highest node degree and mobility based clustering.

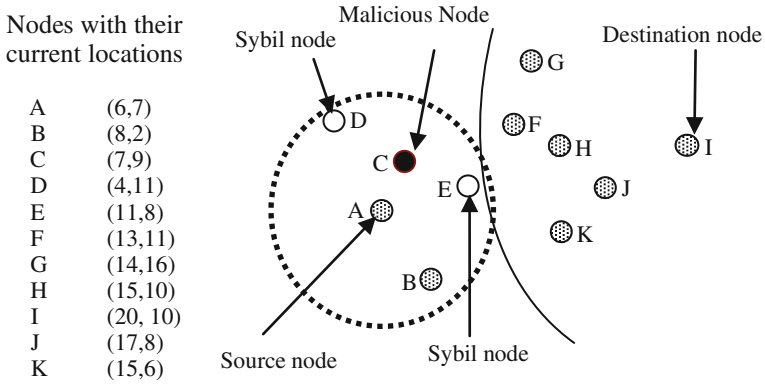


Fig. 3 A MANET topology with 11 nodes

Table 1 Location information of A's one hop neighbors

Neighbors of the source node A	Locations of A's neighbors	Distance of A's neighbors from the destination node I [10, 20]
B	(08, 02)	14.42
C	(07, 09)	13.04
D	(04, 11)	16.03
E	(11, 08)	09.22

Sybil Attack in Lowest ID Clustering Algorithm. In lowest ID algorithm [7], a node with the minimum ID is chosen as a clusterhead. Each node is provided with a unique ID and it periodically broadcasts the list of its neighbor's IDs, including itself. A node which only hears nodes with ID higher than itself is a clusterhead (CH).

Figure 4a shows a schematic of the result of using lowest ID clustering. There are 11 nodes with unique IDs, which form a connected graph. After the Lowest-ID clustering algorithm is executed, three clusters are formed, as depicted by the dotted circles. The black colored balls inside each cluster represent the clusterheads (1, 5 and 3 in Fig. 4). The striped balls (6 and 7) that are within the communication range of two or more different clusters represent the gateway nodes and the empty balls are the member nodes.

To become a cluster head, a malicious node can present the Sybil node with lowest ID in its neighborhood. For this, the malicious node will have to behave normally for the period until it has accessed the information about the whole network i.e. its one-hop, two-hop and n-hop neighbors and their respective IDs. After gaining the appropriate information, the malicious node can introduce its Sybil node with lowest ID, to fulfill its purpose by becoming the clusterhead. The attack becomes more devastating and difficult to be detected if the malicious node introduces its fake identities (Sybil nodes) by varying the transmission power. It takes the advantage of varying the transmission power in two ways: First, it cannot be detected on the basis

Blank circle: Member node
Black circle: Head node
Striped circle: Gateway node

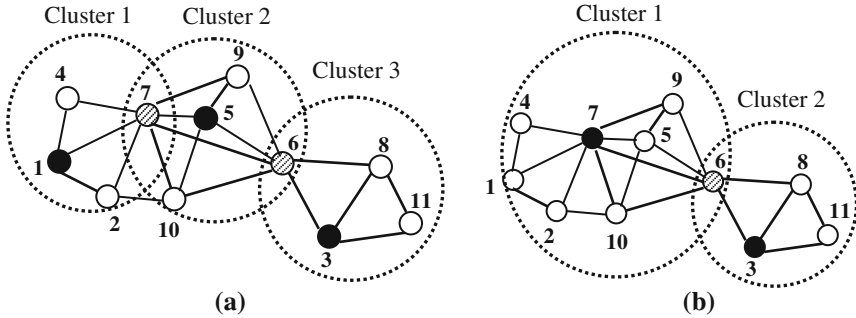


Fig. 4 Cluster formation process. **a** Lowest ID approach. **b** Highest node degree approach

of same signal strengths of its Sybil nodes [18]. Second, by decreasing the transmission power for different Sybil nodes, the message will not reach all the legitimate neighbors of the malicious node and hence cannot be detected on the basis of the fact that two different physical entities cannot have the same set of neighbors [19].

The Sybil attack can also disrupt the lowest ID based cluster routing by presenting multiple Sybil nodes with IDs higher than its neighboring legitimate nodes. Here the intention is to make the legitimate node with lowest ID, the clusterhead again and again to drain its battery. Once the battery is drained completely, the malicious node can impersonate its ID for one of its Sybil node to become a clusterhead.

Sybil Attack in Highest Node Degree Algorithm. In highest node degree algorithm [8], the degree of a node is computed on the basis of its neighbors. The node having maximum number of neighbors is elected as the clusterhead. If there is a tie between two or more nodes in terms of node degree, the node with lowest ID is chosen to be clusterhead. Figure 4b shows the result of using highest degree clustering for the same topology that was being used for the lowest ID algorithm.

The highest degree algorithm can also be disrupted by the Sybil attack. By presenting multiple Sybil nodes, a malicious node may claim to have more neighbors than the actual number. For example, in the Fig. 5, the node 5 is a malicious node with nodes 3, 4 and 6 as its one hop neighbors (hence node degree 3). The node 4 has the maximum node degree of 5 among its neighbors and should to be selected as a cluster head. But, the malicious node 5 also includes its three Sybil node, i.e. S_1 , S_2 and S_3 so as to increase its node degree to 6 and hence becomes the clusterhead. Now the question is how to introduce these Sybil nodes to the legitimate neighboring nodes, i.e. with direct communication or indirect communication.

If indirect method of communication is followed, the malicious node will claim to have the specified number of Sybil identities as its neighbors and will not allow them to communicate directly with its legitimate neighboring nodes. But, due to mobile