Secure Routing for Mobile Ad-hoc Networks

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CS625: Advanced Computer Networks



- Mobile Ad-hoc Networks
 - Introduction
 - MANET Routing Protocols
 - Security in MANET Routing
- Security by Offline Initialisation
 - Introduction
 - Example: Ariadne
- Security by Bootstrapping
 - Introduction
 - Bootstrapping using SUCV
- 4 Conclusion



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Need

- Often setting up an infrastructure is infeasible
- Disaster relief
- Community networks (OLPC)
- Military applications
- Enter MANETs

Challenges

- No infrastructure
- Wireless (duplicate, delayed packets)
- Mobility
 - Highly dynamic topology
- Devices are usually resource-limited

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Classification

- Table-driven / Proactive
 - Nodes periodically share their routing information with all others
 - Every node has routing information for the entire network
 - Problems w.r.t. efficiency, scalability
 - DSDV, CGSR
- On-demand / Reactive
 - First attempt at making a connection triggers Route Discovery
 - Subsequently require Route Maintenance in case nodes in a route go down
 - Drawback setup time for first connection is high
 - AODV, DSR, TORA



Example: DSDV

- Table-driven protocol
- Remember Distance Vector routing?
 - And the count-to-infinity problem?
- DSDV: Destination Sequence Distance Routing
 - Use sequence numbers to tackle count-to-infinity
 - Destination node gives an even sequence number to its own updates
 - If a neighbour finds a destination down, sends updates with next odd sequence number
 - Nodes use routing information with the newest sequence number (or the one with the best metric if the sequence numbers are the same)

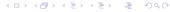


Example: DSDV

- Some optimisations
 - Send a "full dump" initially and incremental updates periodically
 - Measure average time between first and best updates for each destination
 - Defer future updates for that time period

Example: Dynamic Source Routing

- On-demand protocol
- Route Discovery
 - Source broadcasts a "route request" message containing the destination and a broadcast ID
 - If an intermediate node does not have a route, it forwards the request, appending its own address
 - Intermediate nodes only forward the first instance of the request they see
 - The destination gets the request with the list of intermediate nodes and sends back this list using the reverse route, or using another route request
 - The source now does source routing using this path
- Route maintenance
 - "Route error" messages for broken links and acknowledgments to ascertain link status



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Attacks

- Routing disruption
 - Loop creation
 - Blackholes (route all packets through self)
 - Blackmail (force blacklisting of a node)
 - Force suboptimal routing
 - Partition the network
 - Wormholes (require collusion, hard to tackle)
- Resource consumption
 - Flood control messages

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Introduction

- First set of protocols assume some form of initialisation independent of the ad-hoc network
- Single shared secret
 - One compromised node compromises the network
- Trusted KDC
 - Introduces some infrastructure
 - Single point of failure
- Asymmetric cryptography is an option
 - Expensive for low-capacity nodes
- One-way hash chains



One-way Hash Chains

- Used to authenticate messages from a sender
- We are given a publicly known one-way hash function, H
- Sender generates a random seed, x, and a set of n keys as follows
 - $k_0 = x$
 - $k_i = H(k_{i-1})$
- Receivers are preconfigured with k_n for each sender
- One key per message sender sends encrypted/signed message and key
- Messages is valid if there if H^j (key) is equal to some previously received key



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TESLA

- Every node has a one-way hash chain
- A node releases keys as per a commonly known schedule
- Requires loose time synchronisation (upto Δ drift)
- ullet Let maximum end-to-end delay be au
- For each message, sender attaches a keyed MAC using a key that will be not be published before $(\tau + 2\Delta)$ time units from time of sending
- Receiver verifies the TESLA condition
 - The key with which the message has been signed has not yet been published
 - The key will be disclosed soon enough
 - Buffers the packet and waits till the key is published



Ariadne

- Ariadne is based on DSR
- Also assumes pair-wise shared secrets for all source-destination pairs (but can be done without)
- Route request
 - $h_0 = MAC_{SD}(msg)$
 - Source sends $\langle src, dst, id, t_i, h_0, (), () \rangle$
 - An intermediate node, X, verifies that t_i is valid
 - $h_X = H(X, h_{X-1})$
 - $M_X = MAC_{X_{t_i}}(msg)$
 - X sends $\langle src, dst, id, t_i, h_X, (..., X), (..., M_X) \rangle$
 - Receiver can calculate h₀, and can thus validate the request (for the most part)



Ariadne

Route reply

- $M_{dst} = MAC_{DS}(msg)$
- Receiver sends ⟨dst, src, id, t_i, nodelist, hashlist, M_{dst}, ()⟩
- Intermediate nodes wait for X_{t_i} to be published and then attach it the list at the end
- Source can now verify the destination MAC, and that of each node in the route

Route error

- If a node finds the next hop is unreachable, sends a Route Error to the source
- Again use Tesla for authentication
- \(\sindr, \, dst, \, time, \, MAC, \, recentKey \)



Ariadne

- Node in path might not return Route Error messages
 - Get feedback on received packets through some mechanism
 - Use multiple paths, penalising low-reliability paths
 - If an intruder is detected, include a "blacklist" in future route requests
- Route request floods
 - Attacker might flood the network with requests, since these are only finally authenticated by the target
 - Maintain a separate TESLA chain for route requests, and do authentication at neighbours

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Bootstrapping

- Assuming prior initialisation might not be realistic
 - Not all nodes may be administered by a single body
- Hybrid solution
 - Assume at most t nodes can be compromised
 - (n, t + 1) Threshold Cryptography
 - Some nodes have to act as servers
- PGP-like mechanism
- Statistically Unique and Cryptographically Verifiable identifiers

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Bootstrapping using SUCV

- SUCV
 - Every node has a public-private key-pair
 - Address is a hash of the public key
- Again built on DSR
- Route request: source sends (src, dst, id, sig, pubkey, ())
 - Each intermediate node just appends itself to the list at the end
 - Destination can authenticate the request
- Route reply: destination sends
 (route, src, dst, id, (a, b, ...), sig, pubkey)
 - Intermediate nodes cannot tamper, source can verify



Bootstrapping using SUCV

- Route maintenance: intermediate node sends ⟨sndr, dst, sig, pubkey⟩
 - Source can verify that the message originated at sndr
- This mechanism can be used with SEAD, Ariadne, etc.
- Bugs?
 - Intermediate node can add arbitrary routes during route discovery – maybe each intermediate node can append a signature
 - Need timestamps and loose time-synchronisation to prevent replay attacks



Q&A

Thanks!

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