Hacking MANET

Building and Breaking Wireless Peering Networks

Riley “Caezar” Eller

Why or Why Not MANET?

- Ideals
  - Allows seamless roaming
  - Works when infrastructure breaks
  - Routing does not require administration
  - Functional in hostile environments
  - Farther from the Shannon curve due to lower typical transmission distance
- Problems
  - Network scalability
  - Effective, voluntary security

Mobile Networking

- People move a lot
- Fast dynamic routing is a hard problem
- Infrastructure solutions are much easier
- Hybrid infrastructure (or “fixed mesh”) reduces the problem somewhat
- People want a real solution

Here Comes the Science

- Major types of network routing protocols
  - Link State
    - Dyjkstra SPF algorithm
    - Example: OSPF
  - Distance-Vector
    - Bellman-Ford algorithm
    - Example: RIP
  - Policy Based
    - Policies override core DV or LS style routing algorithms
    - Example: BGP

Distance-Vector Routing

- Values
  - Each device has a unique address
  - Applications don’t distinguish transports
  - Robust during partial failure
  - Perceived to be much more natural by users
  - Allows for a high mobility index
- Challenges
  - High processing complexity
  - High message complexity

Link State Routing

- Values
  - Low processing and message complexity
  - Comparatively inexpensive
- Challenges
  - Each interface has a unique address
  - Applications may require transport specific information, such as locally bound IP address
  - Exceptionally unnatural to users
  - Demands a low mobility index

Godzilla Versus Dyjkstra

- Places where LSR (or equivalents) wins
  - The Internet (except as noted below)
- Places where DVR (or equivalents) wins
  - Mesh networks
  - Interior gateway routing
  - Border gateway routing
  - Games and AI

Infrastructure-Mode Wi-Fi

- Immobile
  - Wired equivalency tether
  - Must sacrifice bandwidth exponentially to increase radius linearly
- Inefficient
  - Peer to peer messages eat double bandwidth
  - Close security model requires user intervention

Fixed Mesh Wi-Fi

- Marginal improvement at best
  - Client devices still tethered
  - Same scalability problems among access points
  - Reliable fail-over only by sacrificing footprint
  - Does nothing to improve disaster scenario
  - Worse spectrum allocation
- Lagging standard not due until 2008

What We Really Want

- Peer to peer network
  - Excellent security
  - VOIP and 3GPP reliable delivery
  - Automatic discovery
  - Maximum mobility
  - User defined network policy

Understanding the Link Layer

- Understanding mesh links
  - Nodes beacon to provide carrier sense
  - Discover peers automatically
  - Infer link quality from beacon packet reception
  - Acknowledge high quality beacons
  - Translate link quality into link metric, e.g.:
    - For 802.11b, 99% beacon reception implies about 1200 millisecond expected transmission delay
    - 40% reception implies nearly infinite delay

Attacking the Link Layer

- Eavesdropping
  - Discover participants and topology
  - Retrieve public keys (identity tracking)
  - Content interception
- Sybil Attack
  - Greeting flood
  - Storage or processing denial of service

Attacking the Link Layer

- Greeting and acknowledgement replay
  - Causes link quality overestimate
    - Causes degenerate routing
    - Increases processing and storage requirements
  - Wormhole attack
    - Previous work here by S. Swami and others
    - Will discuss in more detail as a routing layer attack

Attacking the Link Layer

- Unauthorized access
  - Bandwidth reduction
  - Perimeter intrusion
- Selective jamming
  - Freeze the Wi-Fi MAC layer
  - Underestimate link quality
  - Isolate and conquer

Securing the Link Layer

- Link Cryptography
  - – DH/DSA key exchange
    - Gives clear cryptographic session definition
    - Prone to computational denial of service attacks
  - – Work tokens
    - Defend against DOS
    - Leverages desire to join against computation requirements

Securing the Link Layer

- Link Cryptography (continued)
  - Signed broadcasts
    - Exceptional computational cost
    - Prevents wormholes and other forgery attacks
  - Certified identity
    - Translates node identity into comprehensible string
    - Allows user control of policy
    - Impedes unauthorized access

Securing the Link Layer

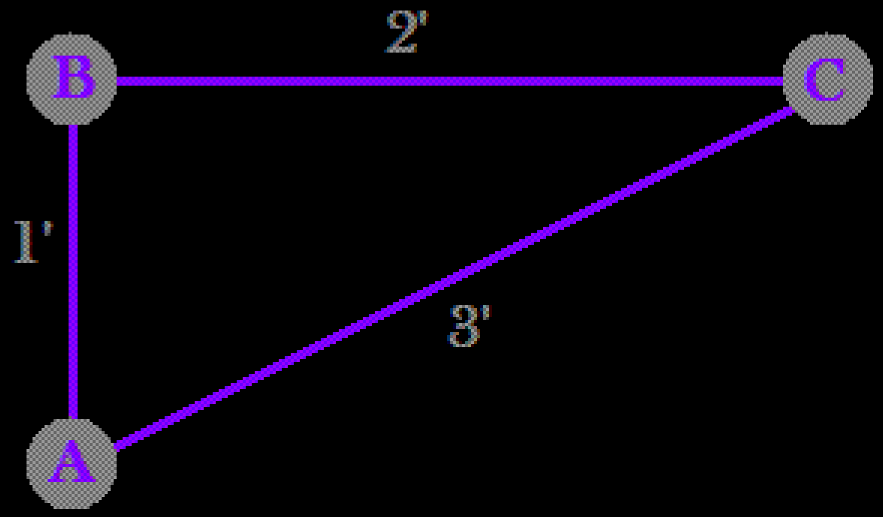
- Other Techniques
  - Jittered timers
    - Greatly reduces risk of sniping
    - Makes selective jamming very difficult
  - Transient MAC address
    - Avoid manufacturer profiling
    - Cycle periodically to throw off listeners

Avenues for Future Research

- Acknowledgement of hidden nodes
  - Destroy two-hop topology graph
- Ubiquitous acknowledgement
  - Desynchronize link quality estimation
  - Ideal denial of service to perfect links
  - Like a rushing attack, but “from the future” rather than just “faster than allowed”

Understanding the Routing Layer

- Routing is a geometric problem
  - Link quality is driven by signal to noise ratio
  - Signal decreases with the square of distance
- Example
  - $1^2 + 2^2 < 3^2$; thus
  - AB + BC < AC; thus
  - A should route through B to reach C



Understanding the Routing Layer

- Understanding mesh routes
  - Advertisement based, e.g.:
    - Node R hears about node O through node P
    - “Receiver hears about Origin through nearby Peer”
    - Shorthand [R: P->O]
  - Requires temporal quality metric, e.g.:
    - Node R expects a message through P to take 3500 milliseconds
    - Shorthand [R: P = 3500]

Understanding the Routing Layer

- Understanding mesh routes (continued)
  - – Metric sums over multiple hops, e.g.:
    - [P: O = 3500]
    - [R: O = 3000]
    - [R: P->O = 3500]
    - R->O = 6500
  - – Algorithms need help to avoid routing loops
    - Must never accept older or slower information
    - Must track edition numbers to deal with asynchronicity

Attacking the Routing Layer

- Refusal to participate
  - Black hole
    - Drop all data packets
    - Very easy to detect
  - Gray hole
    - Drop some data packets
    - Discoverability proportional to packet drop ratio

Attacking the Routing Layer

- Underestimating distance
  - – Wormhole
    - Requires sideband packet forwarding
    - Absorbs all traffic within (H-1)/2 hops radius
  - – Invariant violation
    - Causes routing loops which may become packet storms
- Rushing attacks
  - – Exploits “First past the post” duplicate removal algorithm
  - – Example: DNS response spoofing

Attacking the Routing Layer

- Invisible “Million Man March”
  - Sybil attack on steroids
  - Flattens scaling topology
  - Destroys local routing efficiency

Defending the Routing Layer

- Trust-based link selection
  - Assume minimal trust of each peer initially
  - Increase trust slowly, decrease rapidly
  - Apply trust multiplier to advertised link cost
  - Contains and localizes damage by harming reputation of naïve intermediaries

Defending the Routing Layer

- Signed control messages
  - Computationally expensive
  - Eliminates rushing and wormhole attacks
- End-to-end validity probe
  - Augment trust metrics with cryptographically secure data or control message
  - Makes Sybil attacks expensive since identities are periodically required to respond

Conclusions

- With MANET we can have…
  - Discovery
  - Identity
  - Quality
  - Efficiency
- But **first** we need…
  - Scalable routing algorithm
  - Hardware cryptography
  - Fixes for 802.11 Ad Hoc

Going Forward

- What you can do to hurry the future
  - Seek out and play with emerging protocols
  - Develop P2P phone applications
  - Demand hardware crypto on small devices
  - Use Thin-MAC wireless cards
  - Hack It!