Denial of Service in Sensor Networks

Authors : Anthony D. Wood
John A. Stankovic
From: University of Virginia

Presented by: Luba Sakharuk

Agenda for the DOS in Sensor Networks

- Abstract
- Theory and Application
- The Denial of Service Threat
- Physical Layer
- Link Layer
- Network and Routing Layer
- Transport Layer
- Protocol Vulnerabilities
- CONCLUSION

Abstract

•Unless their developers take security into account at design time,

•sensor networks and the protocols they depend on will remain vulnerable to denial-of-service attacks

•DoS attacks again sensor networks may permit real-world damage to the health and safety of people

•The limited ability of individual sensor nodes to thwart failure or attack makes ensuring network availability more difficult

Theory and Application

•Developers build sensor networks to collect and analyze low-level data from an environment of interest

•Sensor networks maybe deployed in a host of different environments

•Possible Uses:

- Military (battlefield conditions, track enemy movement, monitor secured zone for activity, measure damage, casualties

- Could form communications network for rescue personnel at disaster sites, they could help locate casualties

- Could monitor conditions at the rim of volcano, along an earthquake fault, around critical water reservoir

- Could provide always0on monitoring of home healthcare for the elderly, detect chemical or biological thread at airport

Theory and Application

Security issues for the USES listed on the previous slide:

- **Disasters - It may be necessary to protect the location and status of casualties from unauthorized disclosure (particularly if the disaster relates to ongoing terrorist activities instead of natural causes)**

- **Public Safety - False alarms about chemical, biochemical, or environmental threats could cause panic or disregard for warning systems. An attack on the system's availability could precede a real attack on the protected resources**

- **Home healthcare - Because protecting privacy is paramount, only authorized users can query or monitor the network. These networks also can form critical pieces of an accidental-notification chain, thus they must be protected from failure**

The Denial of Service Threat

•DoS attack is any event that diminishes or eliminates a network's capacity to perform its expected function

•Each layer is vulnerable to different DoS attacks and has different options for its defense

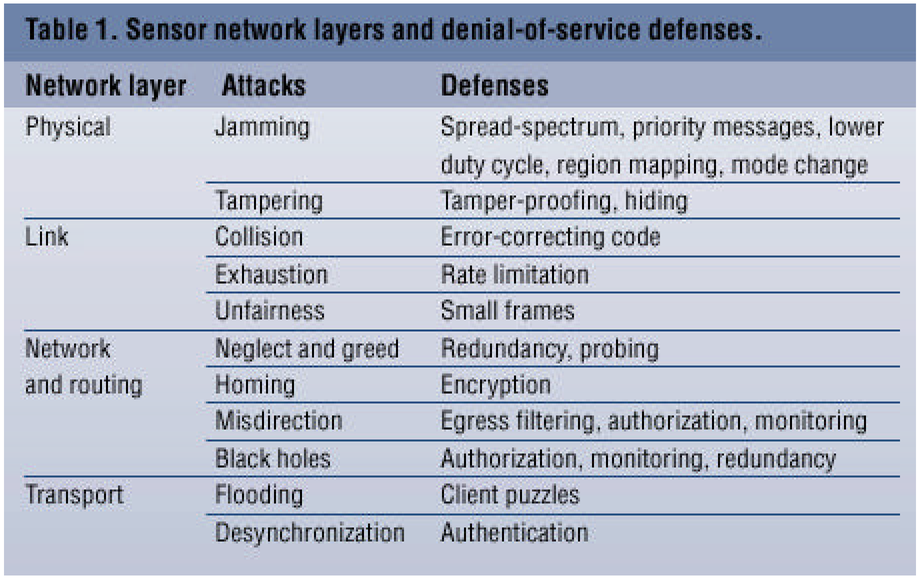


Table 1. Sensor network layers and denial-of-service defenses.

Network layer	Attacks	Defenses
Physical	Jamming	Spread-spectrum, priority messages, lower duty cycle, region mapping, mode change
	Tampering	Tamper-proofing, hiding
Link	Collision	Error-correcting code
	Exhaustion	Rate limitation
	Unfairness	Small frames
Network and routing	Neglect and greed	Redundancy, probing
	Homing	Encryption
	Misdirection	Egress filtering, authorization, monitoring
	Black holes	Authorization, monitoring, redundancy
Transport	Flooding	Client puzzles
	Desynchronization	Authentication

•Hardware failures, software bugs, resource exhaustion, environmental conditions, any complicated interaction between these factors can cause DoS

Example of Route Discovery mechanism

DSR - **D**ynamic **S**ource **R**outing

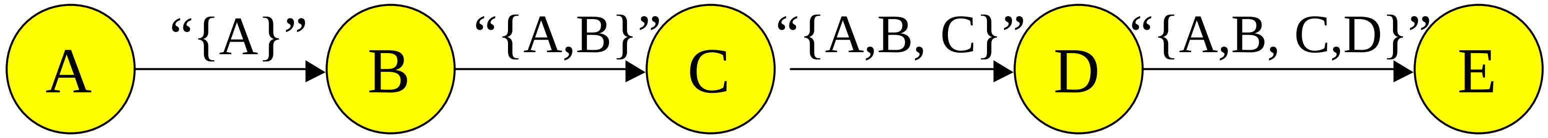
-Uses source routing rather than hop-by-hop routing with each packet to be routed carrying in its header the complete, ordered list of nodes through which the packet must pass

Route Discovery:

1) flood Route request message through network

2) request answered with route reply by

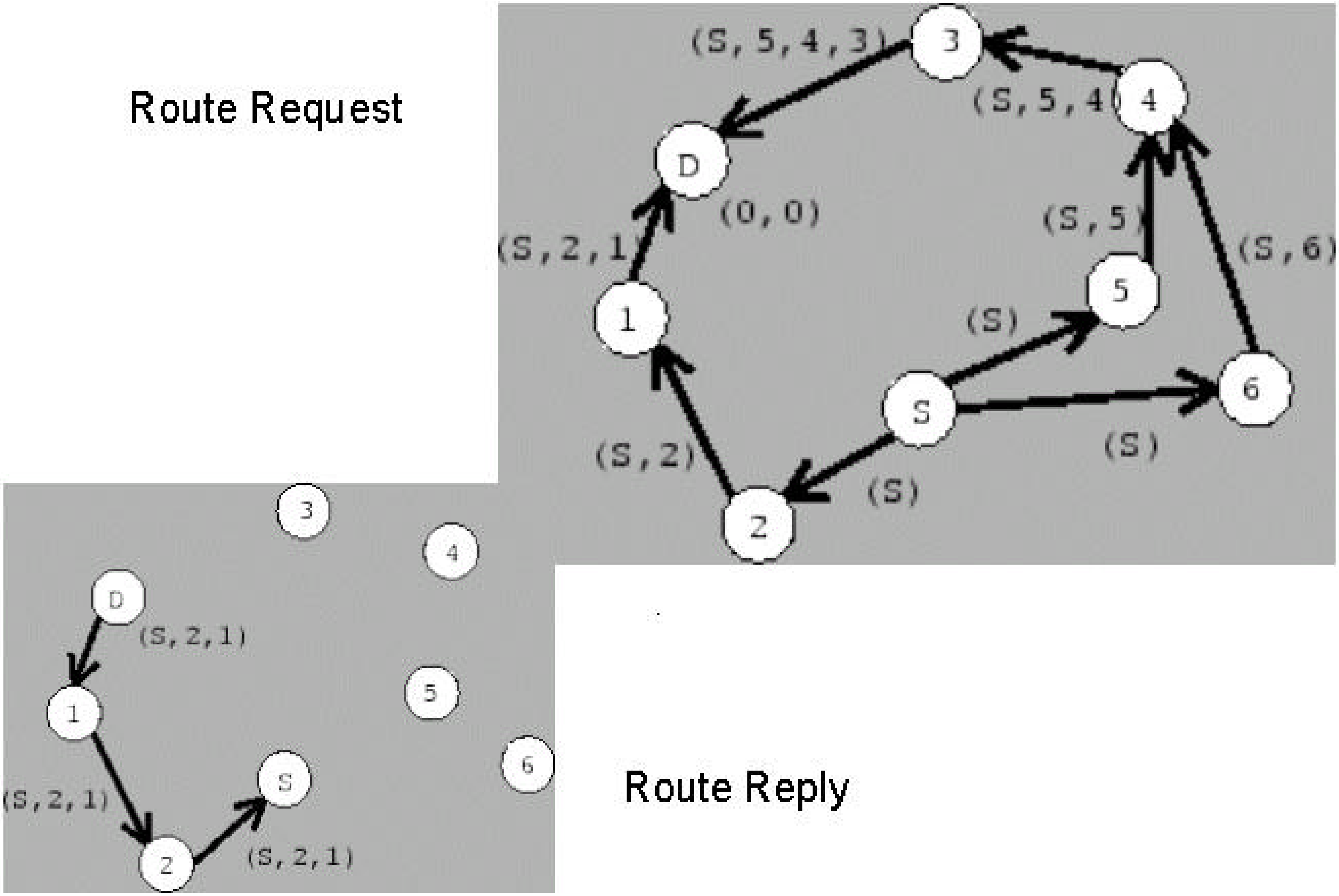
- -destination
- -some other node that knows a path to destination



reply:

“{A,B,C,D,E}”

Example of Route Discovery mechanism



Route Request

Route Reply

Physical Layer

Jamming

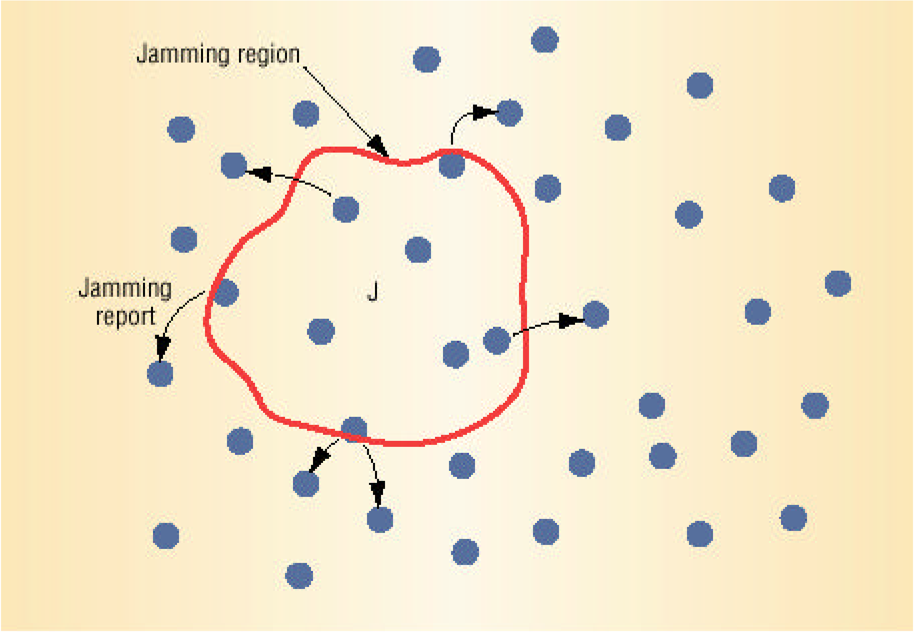


Figure 1. Defense against a jamming attack, phase one. Nodes along the edge of a jammed region report the attack to their neighbors.

Physical Layer

Jamming

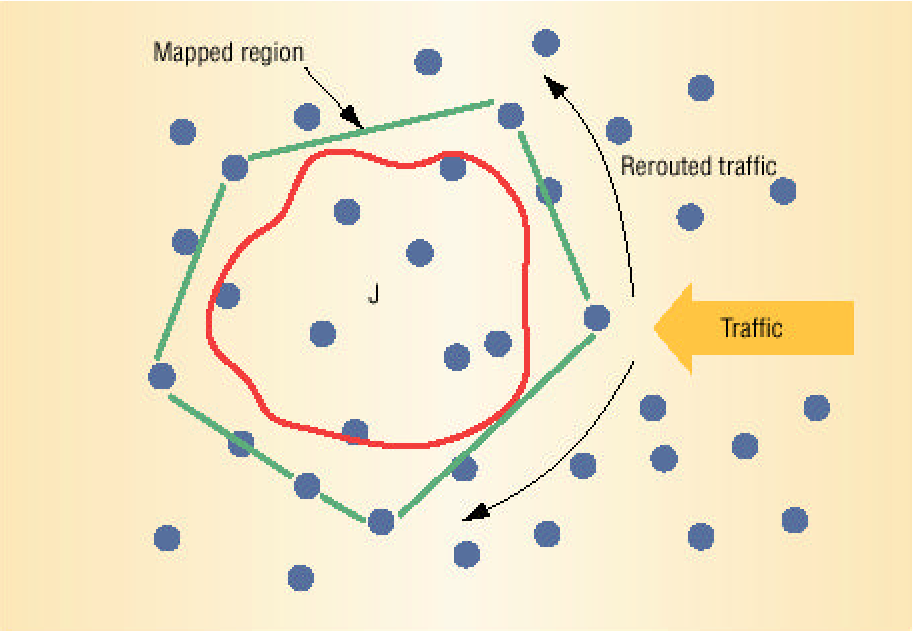
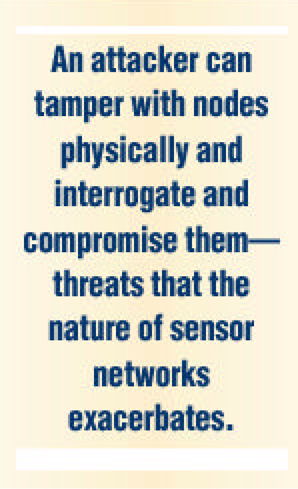


Figure 2. Defense against a jamming attack, phase two. Neighboring nodes collaborate to map the jamming reports, then reroute traffic around the jammed region.

Physical Layer



An attacker can tamper with nodes physically and interrogate and compromise them—threats that the nature of sensor networks exacerbates.

Tampering

1 0 1 1 1 1 1 1 0 0 0 0 0 0 0 0 0 1 0

One defense involves tamper-proofing the node's physical package. Its success depends on

•how accurately and completely designers considered potential threats at design time

•the resources available for design, construction, and test

•the attacker's cleverness and determination

Link Layer

Collision

•A change in the data portion would cause a checksum mismatch at the receiver

•A corrupted ACK control message could induce costly exponential back-off in some MAC protocols

•Malicious collisions create a kind of link-layer jamming

•No completely effective defense is known

Link Layer

Exhaustion

•A naïve link-layer implementations may attempt retransmission repeatedly (even if collisions at the end of the frame)

•This active DoS attack could culminate in the exhaustion of battery resources in nearby nodes

•One solution makes the MAC admission control rate limited, so the network can ignore excessive requests without sending expensive radio transmissions

•One design-time strategy for protection against battery-exhaustion attacks limits the extraneous responses the protocol requires

Link Layer

Unfairness

- **Intermittent application of these attacks can cause unfairness**

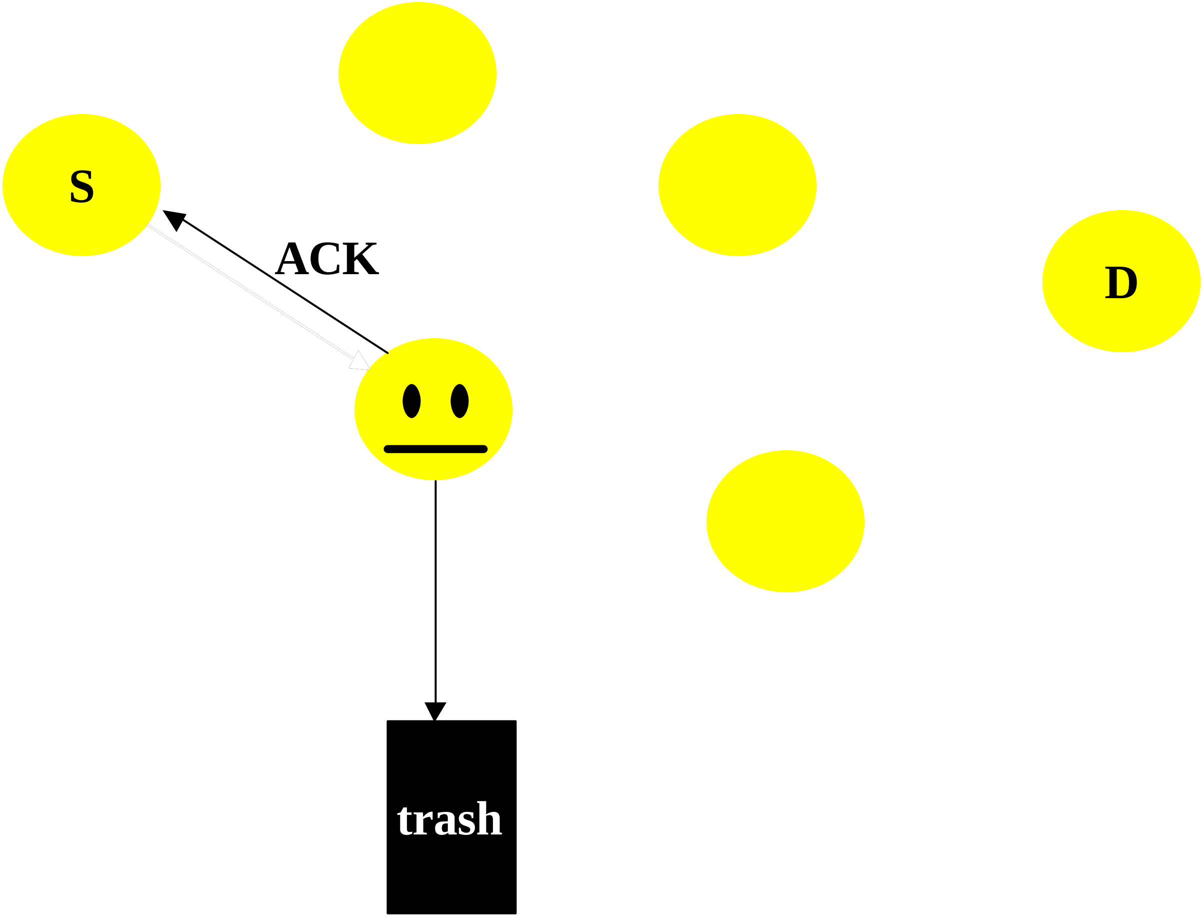
- **May not entirely prevent legitimate access to the channel, BUT**

- **Could degrade service, causing users of a real-time MAC protocol to miss their deadlines**

- **One defense against this threat uses small frames, so that an individual node can capture the channel only for short time**

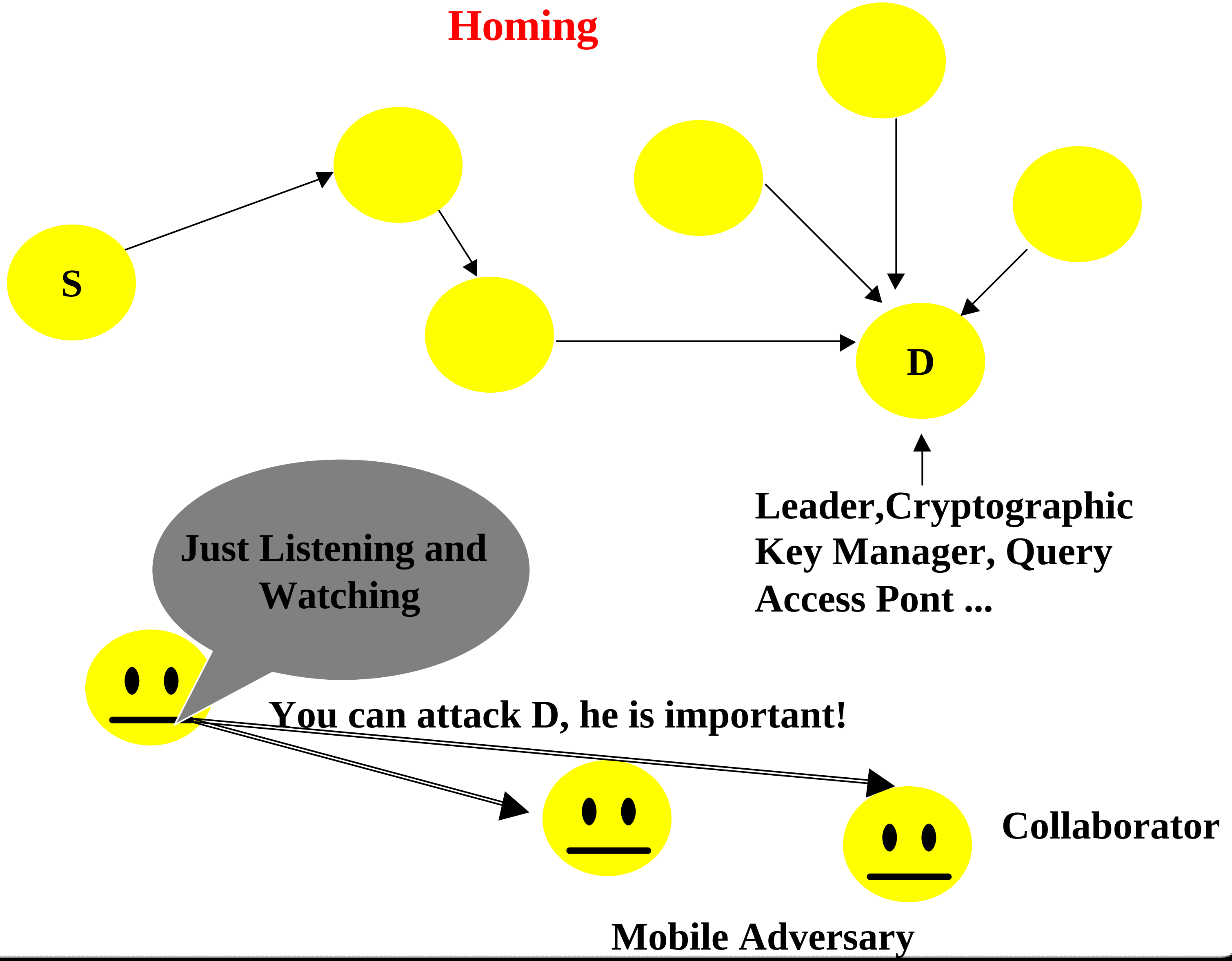
Network and Routing Layer

Neglect and greed



Network and Routing Layer

Homing



Leader,Cryptographic Key Manager, Query Access Pont ...

Just Listening and Watching

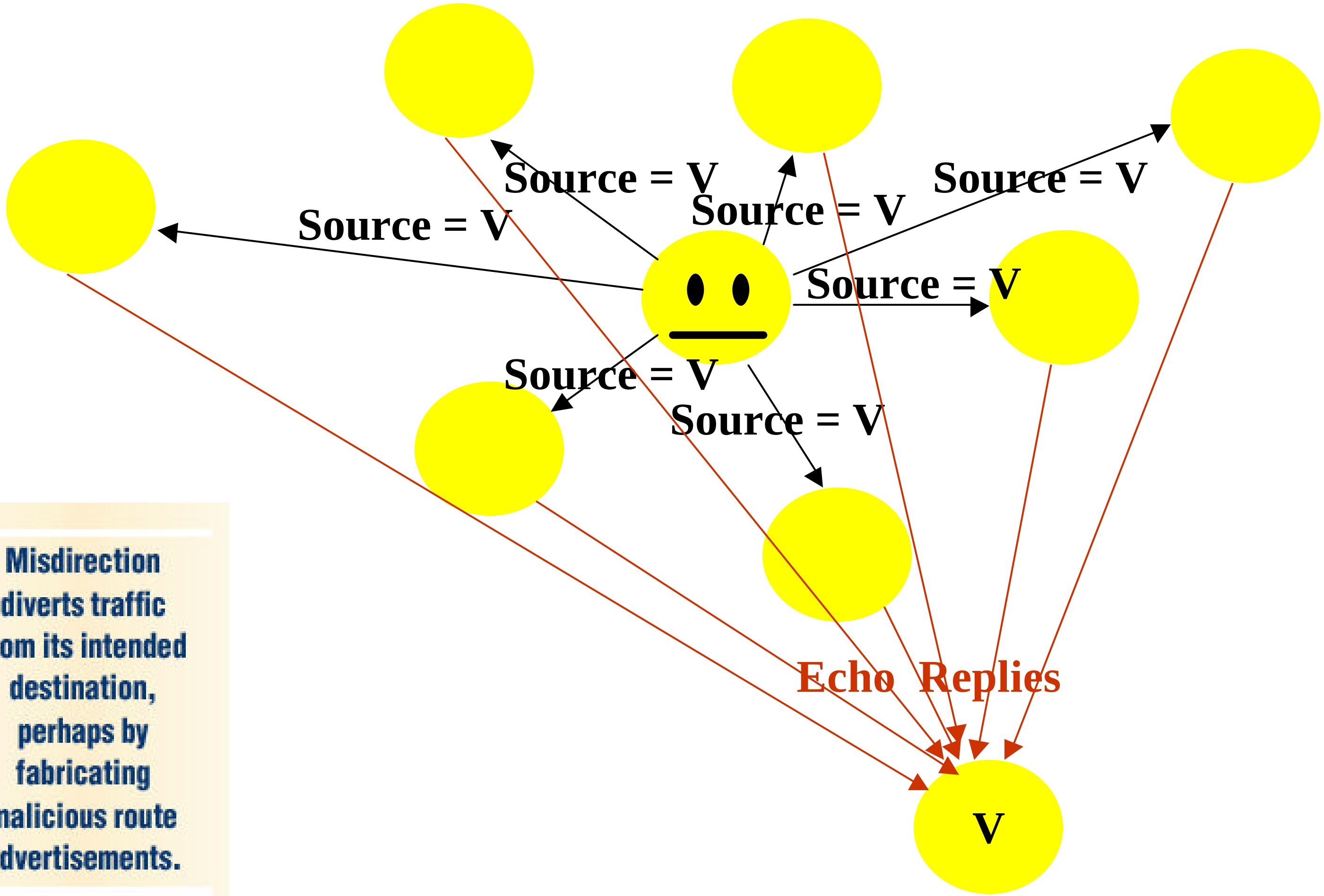
You can attack D, he is important!

Collaborator

Mobile Adversary

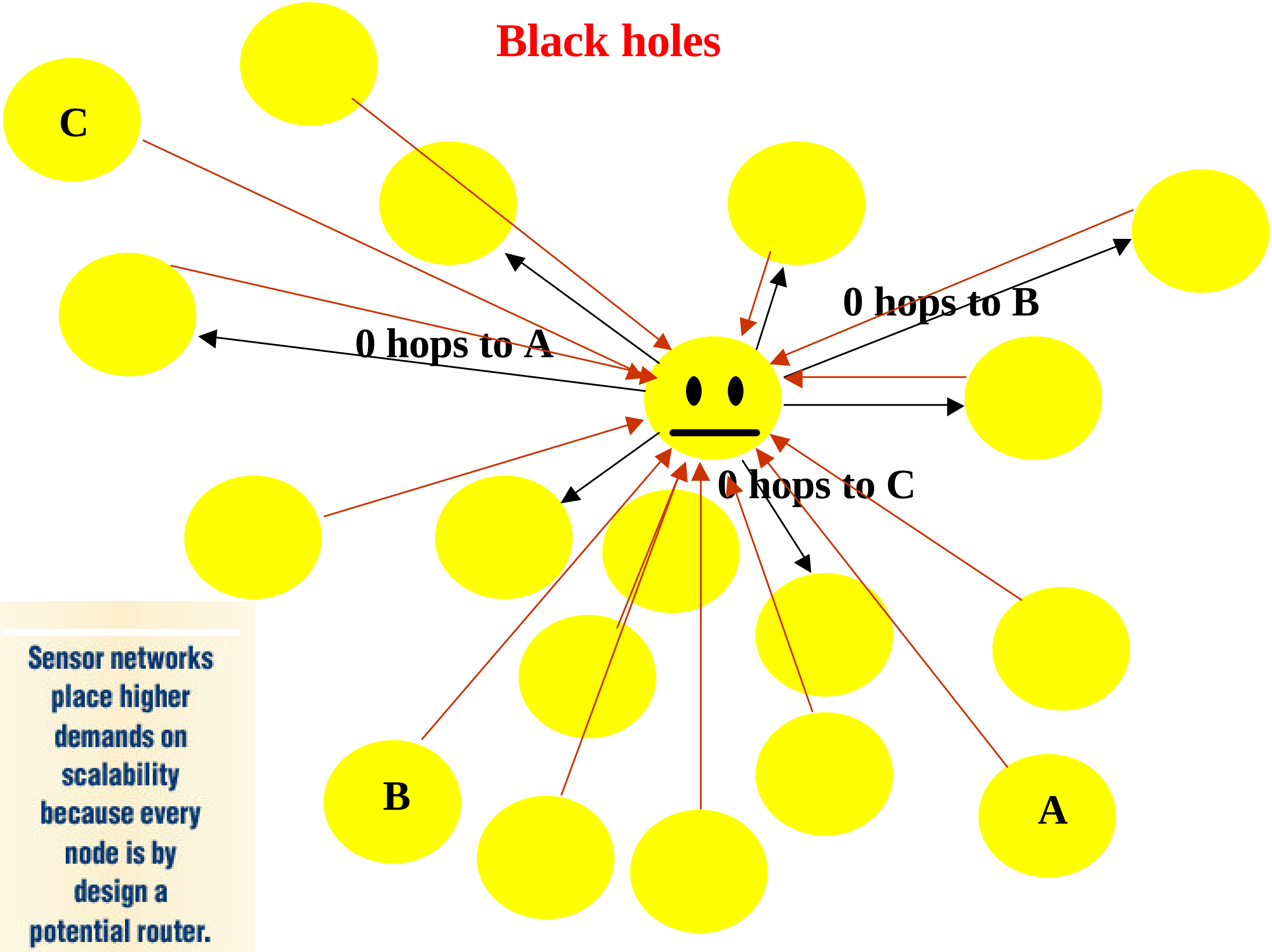
Network and Routing Layer

Misdirection (smurf attack)



Misdirection diverts traffic from its intended destination, perhaps by fabricating malicious route advertisements.

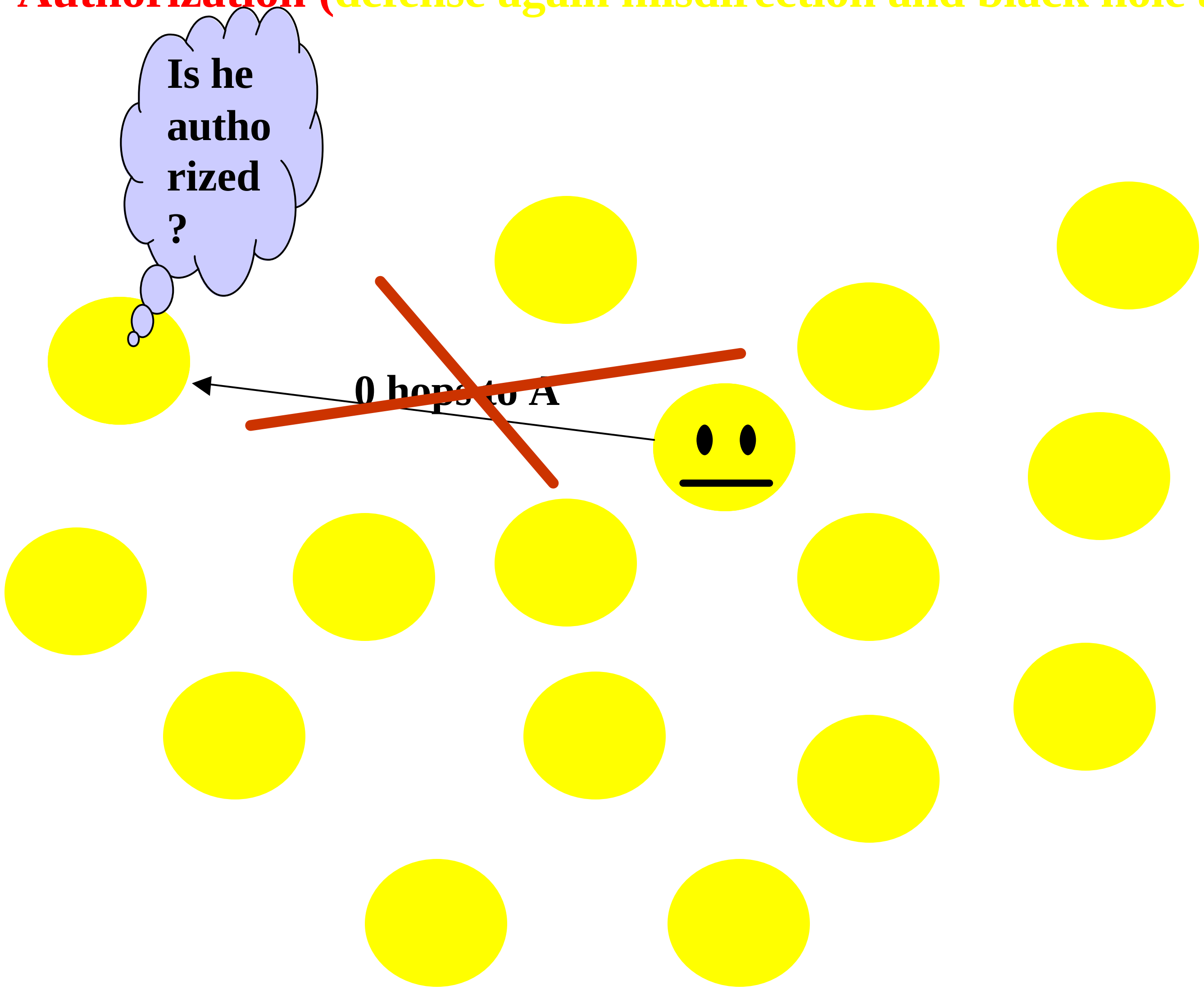
Network and Routing Layer



Sensor networks place higher demands on scalability because every node is by design a potential router.

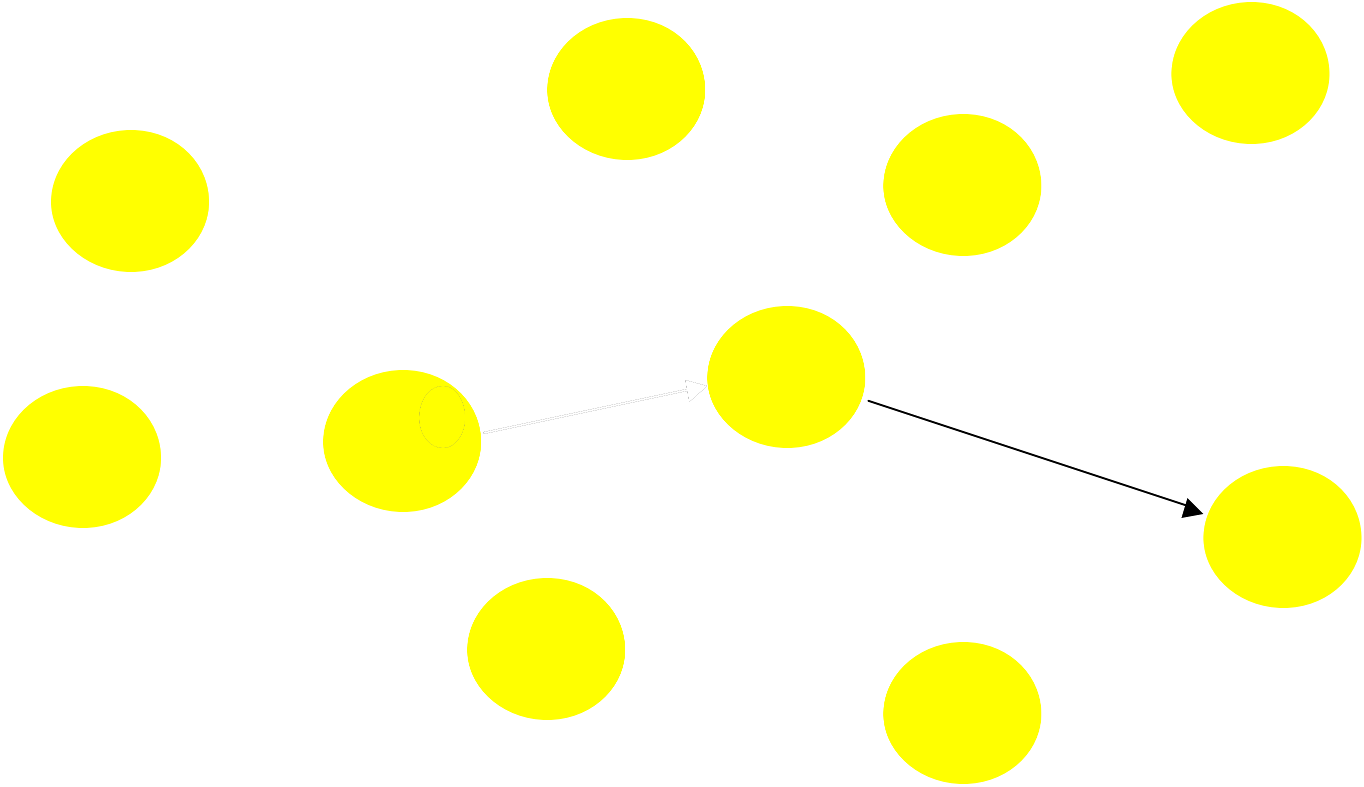
Network and Routing Layer

Authorization (defense again misdirection and black hole attacks)



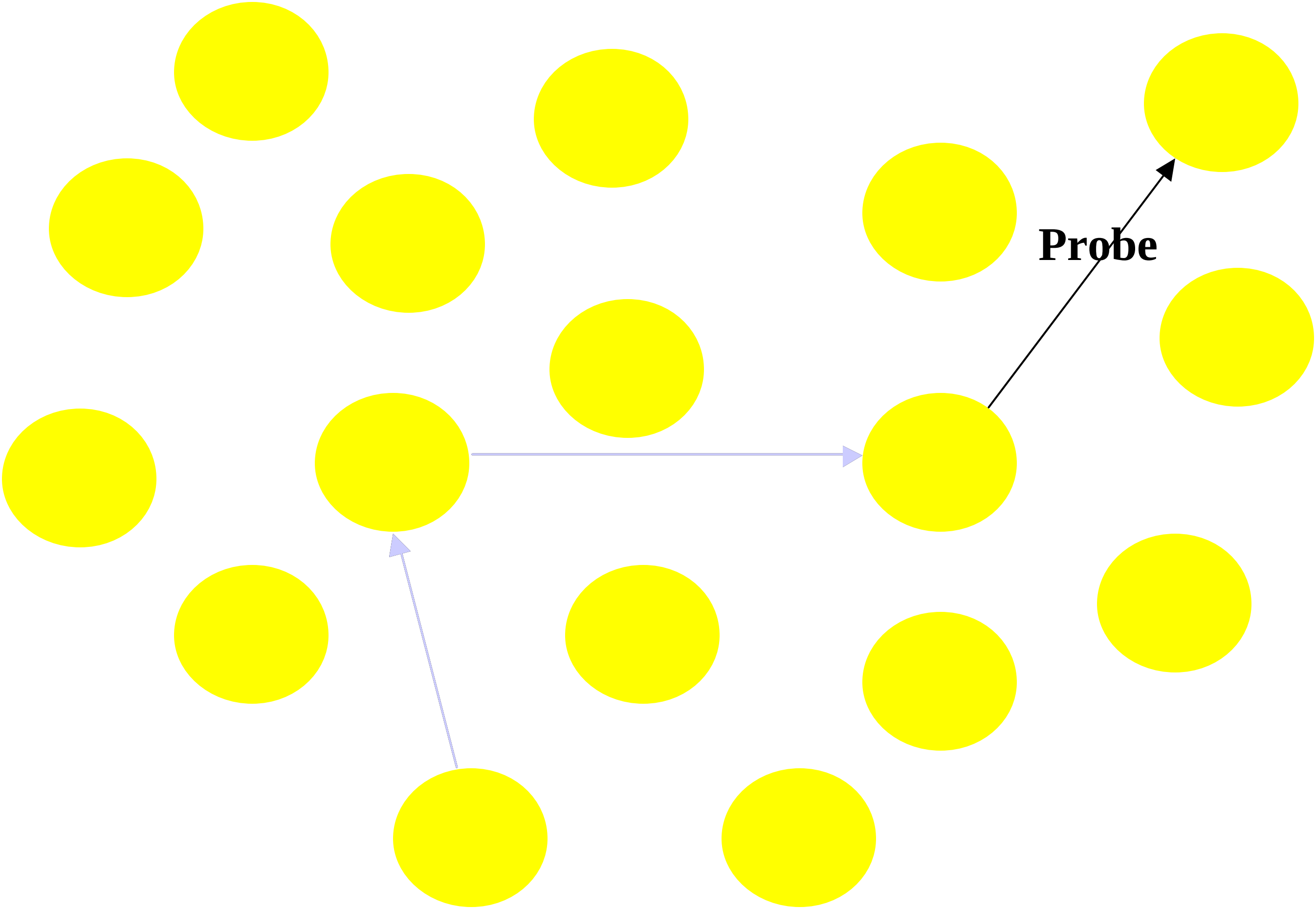
Network and Routing Layer

Monitoring



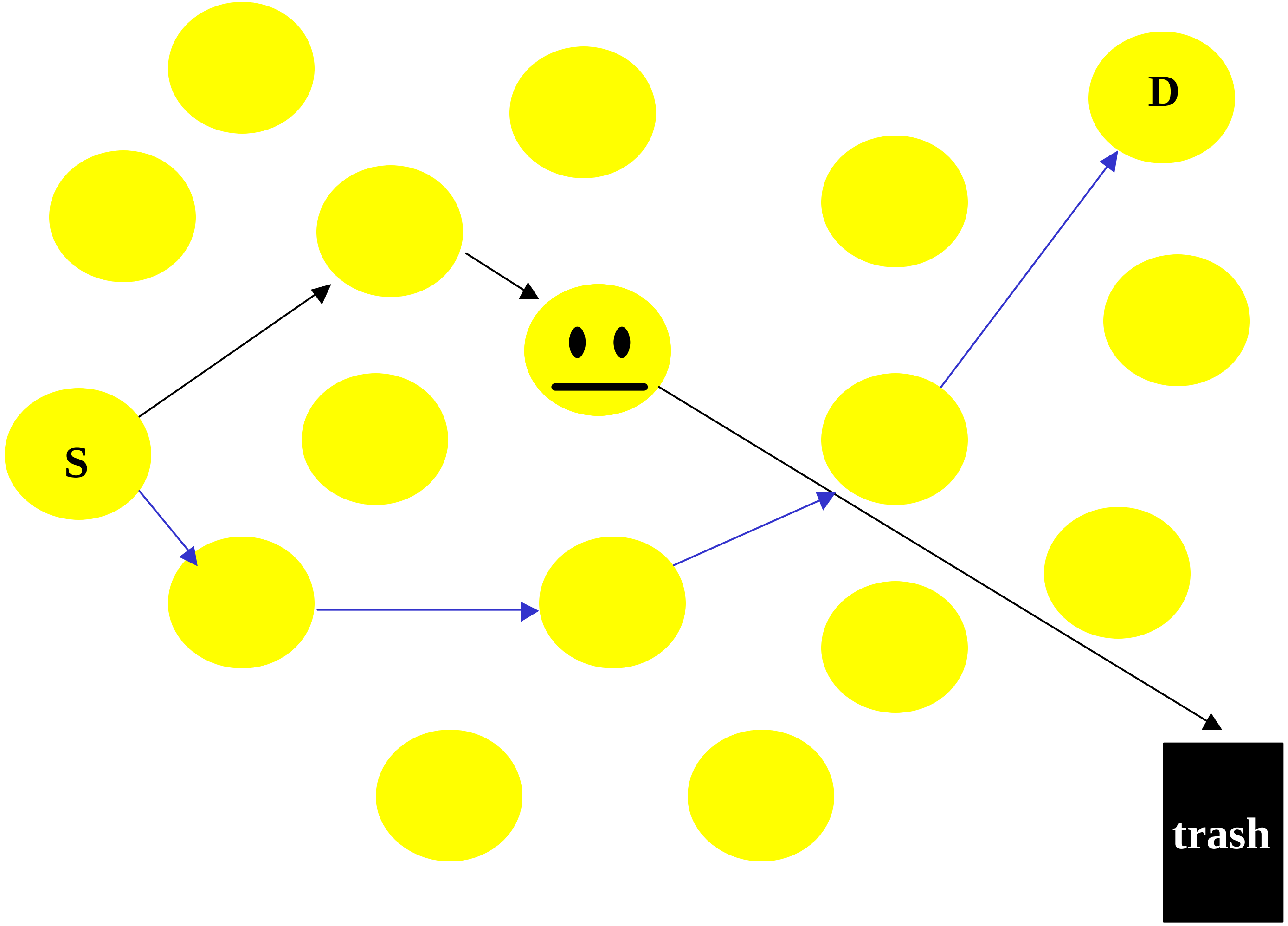
Network and Routing Layer

Probing



Network and Routing Layer

Redundancy



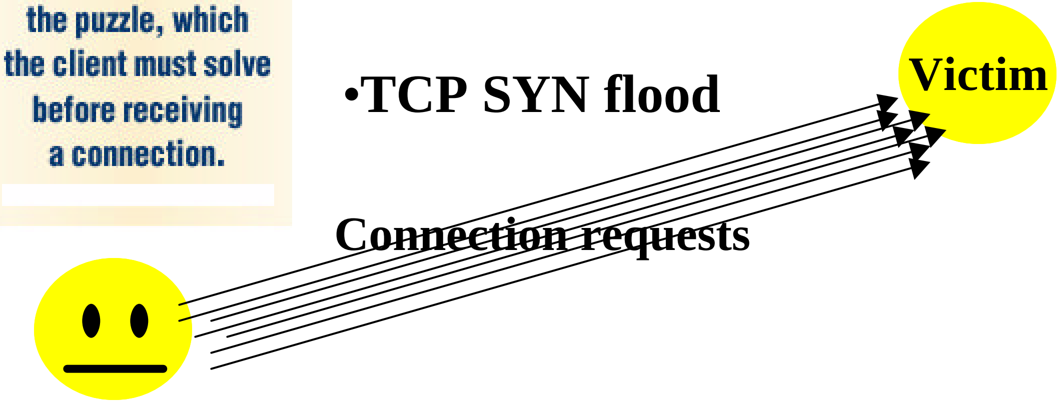
Transport Layer

Puzzles require clients to demonstrate the commitment of their own resources to each connection. Servers distribute the puzzle, which the client must solve before receiving a connection.

Flooding

- Protocols that must maintain state at either end are vulnerable to memory exhaustion through flooding

- TCP SYN flood



Victim

Connection requests

- One defense requires clients to demonstrate the commitment of their own resources to each connection by solving client puzzles

Transport Layer

Desynchronization

Forges messages to one or both end points

- Messages carry sequence numbers that cause the end point to request retransmission of missed frames

- Cause end point waste energy in an endless synchronization-recovery protocol

- One defense to this attack authenticates all packets exchanged

Protocol Vulnerabilities

Adaptive rate control

•Alec Woo and David Culler describe a series of improvement to standard MAC protocols that make them more applicable in sensor networks

•Key mechanisms include:

- random delay for transmissions,
- back-off that shifts an application’s periodicity phase,
- minimization of overhead in contention control mechanisms
- passive adaptation of originating and route-through admission control rates
- anticipatory delay for avoiding multi hop hidden-node problems

Protocol Vulnerabilities

Adaptive rate control

•Woo and Culler propose giving preference to route-through traffic in a admission control by making its probabilistic multiplicative back-off factor 50 percent less than the back-off factor of originating traffic

•This preserves the network's investment in packets that, potentially, have already traversed many hops

•This approach exposes a protocol vulnerability by offering an adversary the opportunity to make flooding attacks more effective.

•High Bandwidth packet streams that an adversary generates will receive preference during collisions that can occur at every hop along their route.

•Thus, the network must not only bear the malicious traffic, it also gives preference to it!

•An attacker can exploit a reasonable approach to power conservation and efficiency

Protocol Vulnerabilities

RAP

•Provides a real-time communication architecture integrating a query-event service API and geographic forwarding with novel velocity monitoring scheduling (VMS) policy

•An attacker can flood the entire network with high-velocity packets to waste bandwidth and energy

•The attack can also amounts to an attacker inducing the node to become a routing black hole

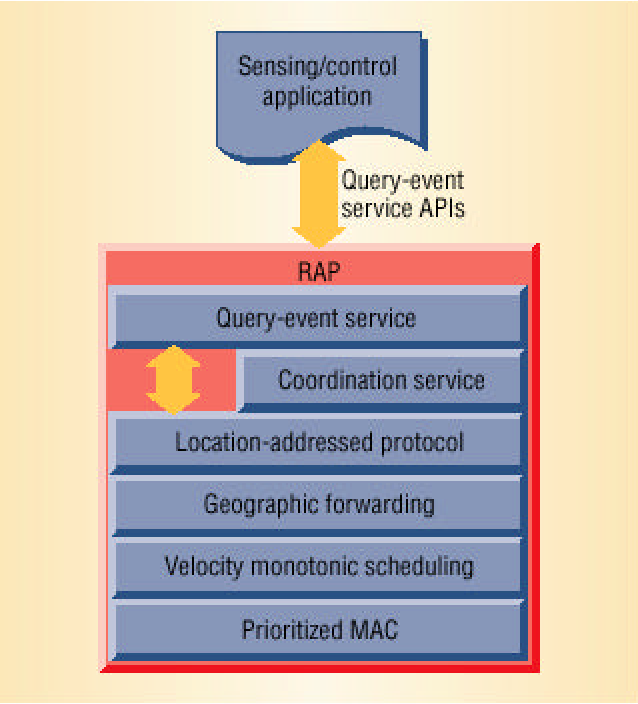


Figure 3. Real-time location-based protocols (RAP) architecture. RAP encompasses several network layers, from a prioritized media-access-control layer to the query-event API just below the application layer.

Conclusion

•**DoS attacks against sensor networks may permit real-world damage to the health and safety of people**

•**Take security into account at design time**

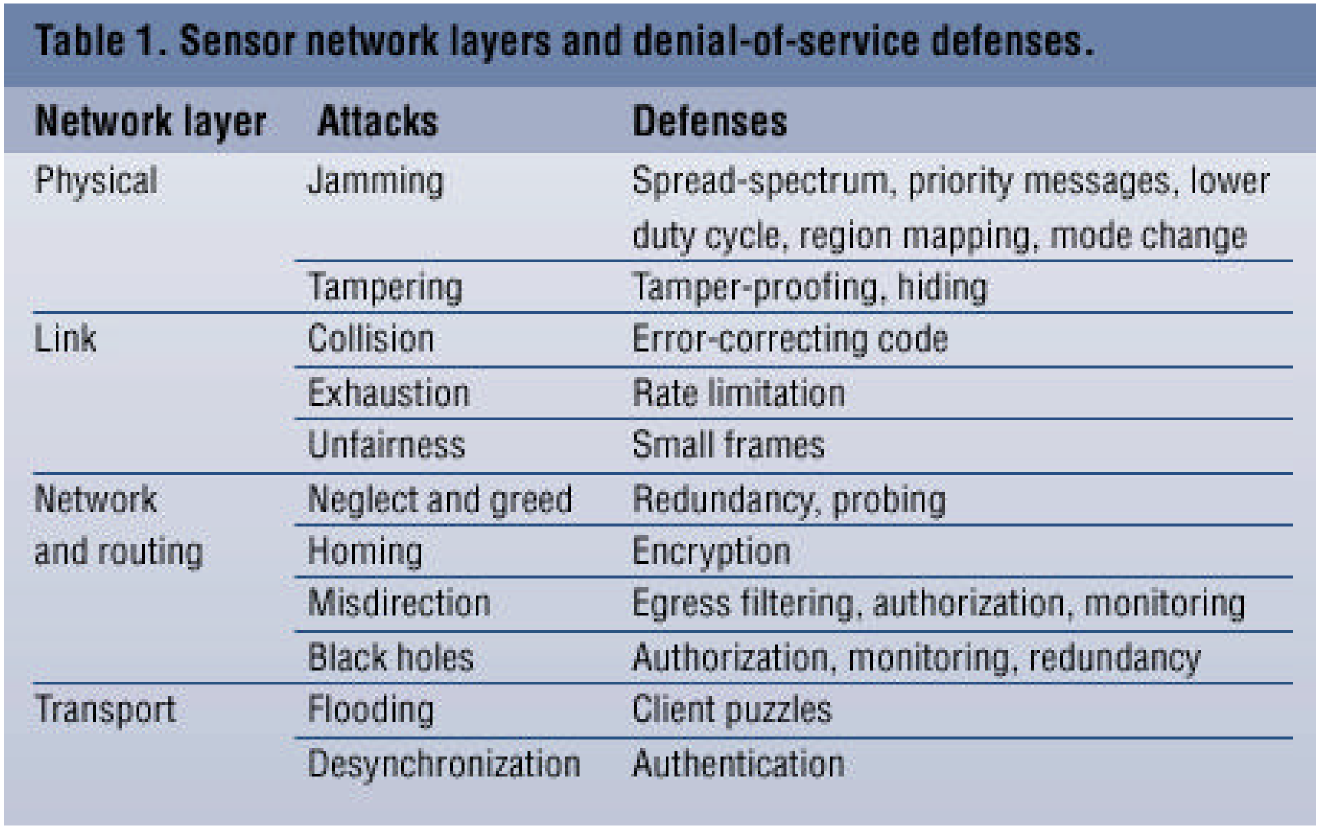


Table 1. Sensor network layers and denial-of-service defenses.

Network layer	Attacks	Defenses
Physical	Jamming	Spread-spectrum, priority messages, lower duty cycle, region mapping, mode change
	Tampering	Tamper-proofing, hiding
Link	Collision	Error-correcting code
	Exhaustion	Rate limitation
	Unfairness	Small frames
Network and routing	Neglect and greed	Redundancy, probing
	Homing	Encryption
	Misdirection	Egress filtering, authorization, monitoring
	Black holes	Authorization, monitoring, redundancy
Transport	Flooding	Client puzzles
	Desynchronization	Authentication