Security in IOT

CHALLENGES AND OPEN QUESTIONS

Internet of Thins

Network of Objects

… a system . . . that would be able to instantaneously identify any kind of object. …

...one major next step in this development of the Internet, which is to progressively evolve from a network of interconnected computers to a network of interconnected objects …

Internet of Things

- Pervasive
- Ubiquitous
- Emerging
- Global

Protection Requirements

Pervasive / ubiquitous

feasible for passive devices

Emerging (may become important)

proper security level

Global

prevents proprietary undisclosed solutions

Connected with Internet

compatible to existing protection

Security in the IoT

- authentication of tags … proof of origin of products
- authentication of readers … access control to tag’s data/configuration
- encryption … privacy – anti-eavesdropping, etc.
- secure point to point connection – data integrity
- signatures by tags/objects … mobile readers and static tags …

The security challenge

Devices are not reachable

- Most of the time a device is not connected

Devices can be lost and stolen

- Makes security difficult when the device is not connected

Devices are not crypto-engines

- Strong security difficult without processing power

Devices have finite life

- Credentials need to be tied to lifetime

Devices are transportable

- Will cross borders

Devices need to be recognised by many readers

- What data is released to what reader?

Security work in an Internet of Things

Assurance

- Risk analysis
- Device analysis
- Crypto capability and export analysis
  - RFID tags will not do crypto for some years
- Security objective
  - Privacy protection
  - Identity protection
  - Traffic analysis protection

Identity and identifier management

- Separation of identity and identifier (see TR 187 010)

I. Communications Security: The TinySec Architecture

"It doesn't matter how good your crypto is if it is never used."

TinySec Design Philosophy

The lesson from 802.11:

Build crypto-security in, and turn it on by default!

TinySec Design Goals:

1. Encryption turned on by default
2. Encryption turned on by default
3. Encryption turned on by default

$\Rightarrow$ Usage must be transparent and intuitive

$\Rightarrow$ Performance must be reasonable

4. As much security as we can get, within these constraints

Challenges

Must avoid complex key management

- TinySec must be super-easy to deploy

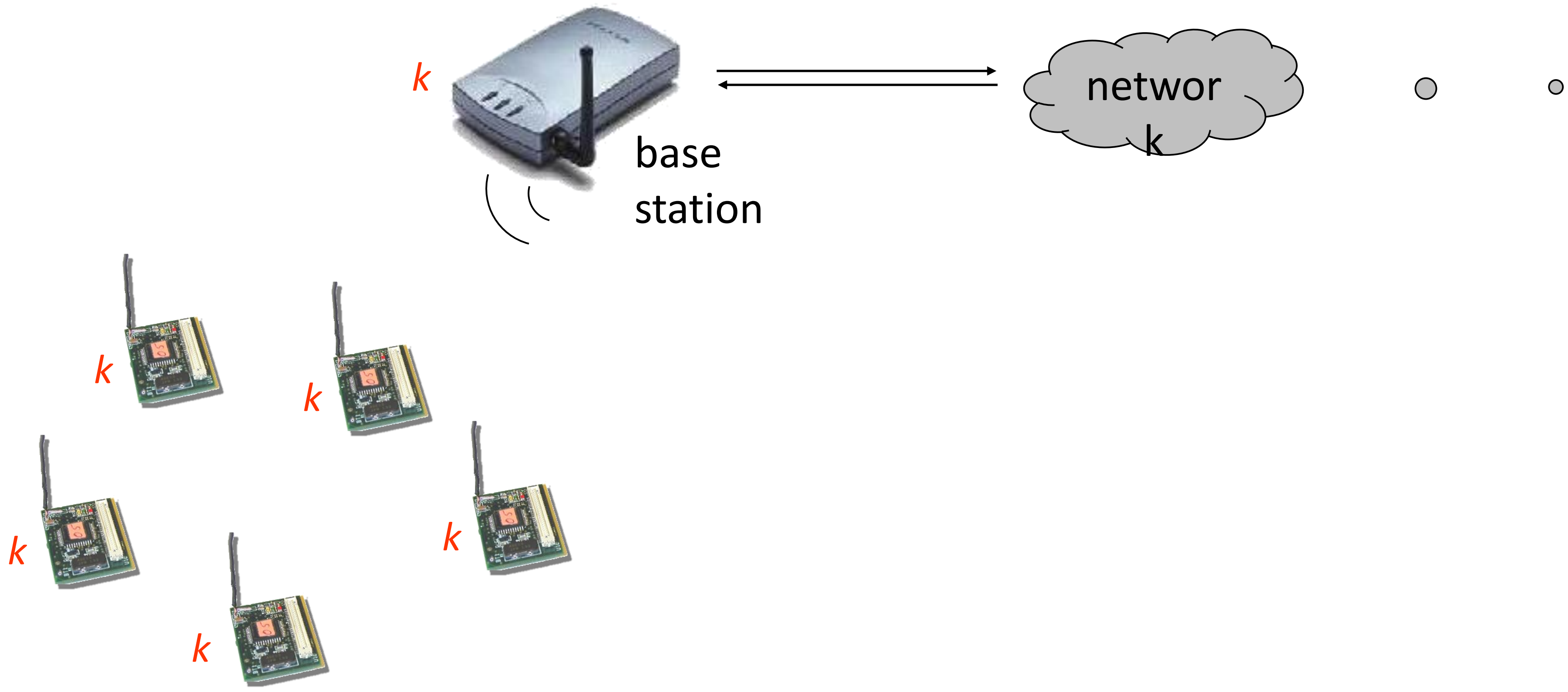
Crypto must run on wimpy devices

- We’re not talking 2GHz P4’s here!
- Dinky CPU (1-4 MHz), little RAM ($\leq$ 256 bytes), lousy battery
- Public-key cryptography is right out

Need to minimize packet overhead

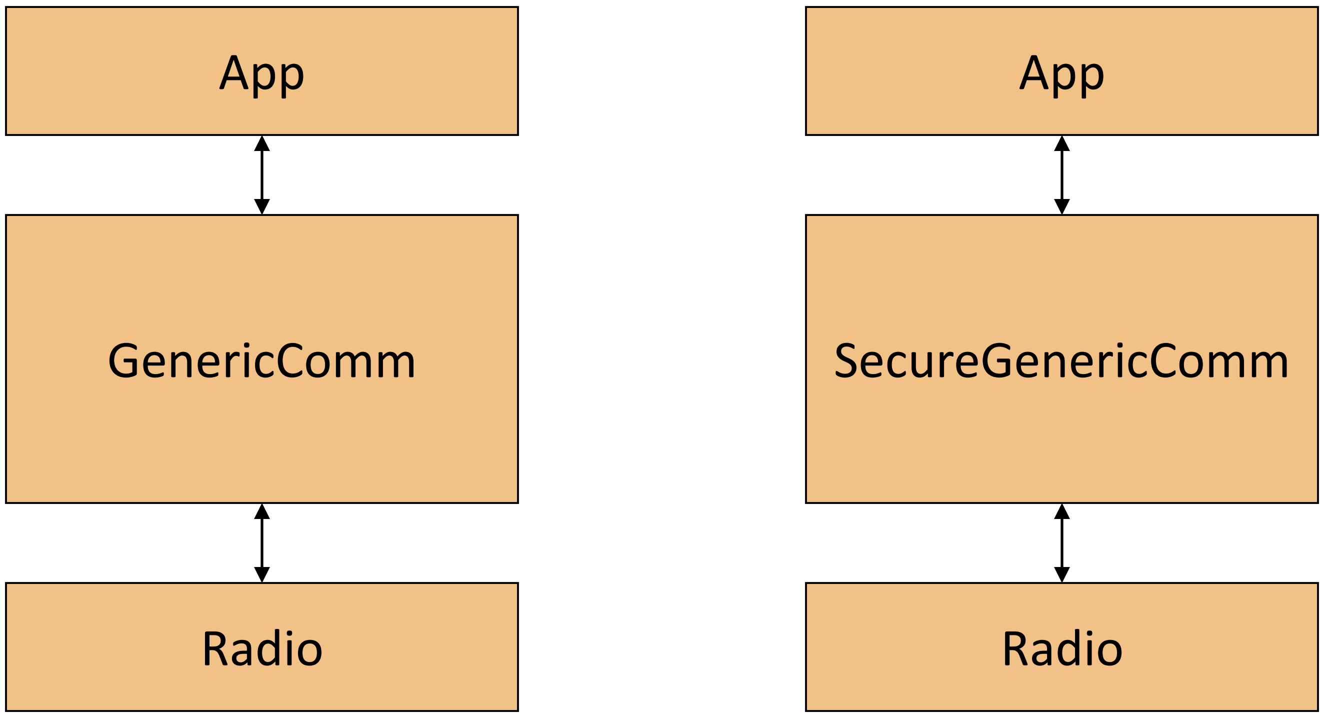
- Radio is very power-intensive:
  1 bit transmitted $\approx$ 1000 CPU ops
- TinyOS packets are $\leq$ 28 bytes long
- Can’t afford to throw around an 128-bit IV here, a 128-bit MAC there

Easy Key Management



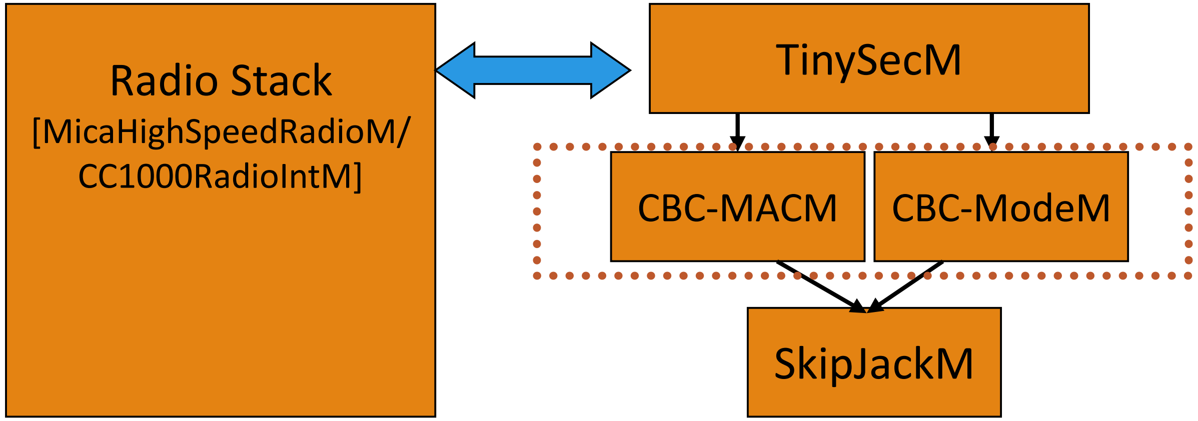
Making key management easy: global shared keys

Be Easy to Deploy



Making deployment easy:
plug-n-play crypto + link-layer security

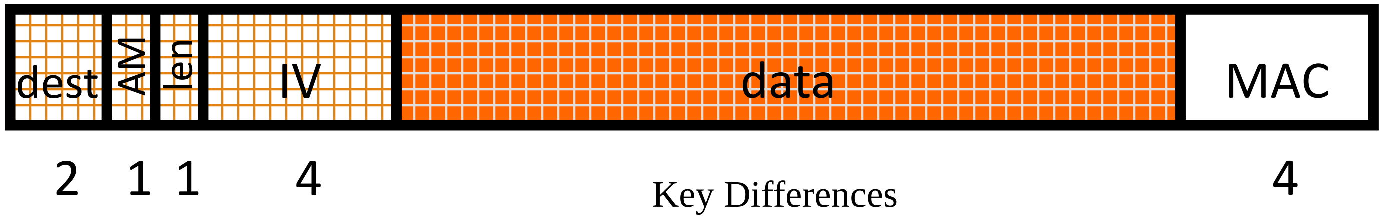
Perform Well on Tiny Devices



Use a block cipher for both encryption & authentication

Skipjack is good for 8-bit devices; low RAM overhead

Minimize Packet Overhead



Encrypted

MAC'ed

Key Differences

No CRC	-2 bytes
No group ID	-1 bytes
MAC	+4 bytes
IV	+4 bytes
Total:	+5 bytes

Minimize overhead: cannibalize, cheat, steal

Tricks for Low Overhead

CBC mode encryption, with encrypted IV

- Allows flexible IV formatting:
  4 byte counter, + cleartext hdr fields (dest, AM type, length);
  gets the most bang for your birthday buck
- IV robustness: Even if IV repeats, plaintext variability may provide an extra layer of defense
- Ciphertext stealing avoids overhead on variable-length packets

CBC-MAC, modified for variable-length packets

- Small 4-byte MAC trades off security for performance; the good news is that low-bandwidth radio limits chosen-ciphertext attacks
- Can replace the application CRC checksum; saves overhead

On-the-fly crypto: overlap computation with I/O

More Tricks & Features

Early rejection for packets destined elsewhere

- Stop listening & decrypting once we see dst addr ≠ us

Support for mixed-mode networks

- Interoperable packet format with unencrypted packets, so network can carry both encrypted + unencrypted traffic
- Crypto only where needed ⇒ better performance
- Length field hack: steal 2 bits to distinguish between modes

Support fine-grained mixed-mode usage of TinySec

- Add 3 settings: no crypto, integrity only, integrity+secrecy
- These come with performance tradeoffs
- Select between settings on per-application or per-packet basis

More Performance Tricks

App-level API for end-to-end encryption

- TinySec focuses mainly on link-layer crypto,
  but end-to-end crypto also has value
- End-to-end secrecy enables performance optimizations (don’t decrypt & re-encrypt at every hop), enables more sophisticated per-node keying, but incompatible with in-network transformation and aggregation; thus, not always appropriate
- End-to-end integrity less clear-cut, due to DoS attacks

TinySec: Current Status

Design + implementation stable

Released in TinyOS 1.1

- Integration with RFM & Chipcon radio stacks; supports nesC 1.1
- Simple key management; should be transparent

Several external users

- Including: SRI, BBN, Bosch

TinySec Evaluation

Wins:

Performance is ok

Integration seems truly easy

Neutral:

Out of scope: per-node keying, re-keying, sophisticated key mgmt; PKI; secure link-layer ACKs

No security against insider attacks;
What if a node is captured, stolen, or compromised?

Losses:

Not turned on by default in TinyOS yet ☹

II. Communications Security: What Crypto Can't Do

"If it's provably secure, it's probably not."
-- Lars Knudsen

Limitations of Crypto

Can’t prevent traffic analysis

Can’t prevent re-transmitted packets

Can’t prevent replayed packets

Can’t prevent delayed packets

Can’t prevent packets from being jammed

Can’t prevent malicious insiders, captured nodes

Crypto is not magic fairy dust;
It won’t magically make insecure services secure.

Isn’t Crypto All We Need?

Crypto doesn’t automatically make X secure, where:

X = network programming

- Attacker could replay old programs

X = time synchronization

- Attacker could delay beacon packets, propagating wrong timing

X = routing

- Some attacks on next slide

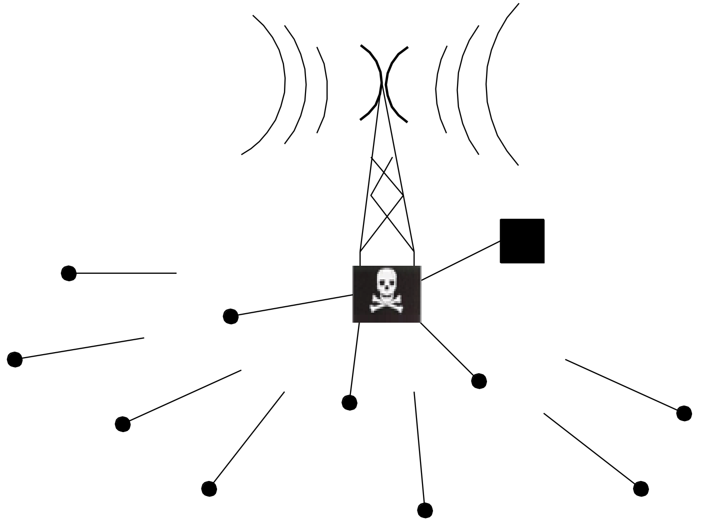
X = localization

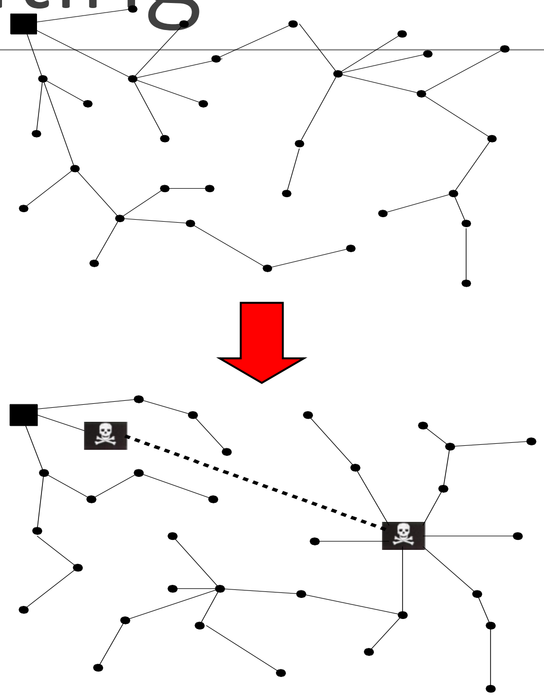
- Attack in three slides

X = aggregation

- Attacks after a few more slides

Example: Attacks on Routing





Hello flood attack:

Broadcast really loudly; then everyone will think you are near them.

Wormhole attack:

Tunnel packets from one part of the network and replay them in a different part.

Protocols analyzed in [KW03]

Protocol	Relevant attacks
TinyOS beaconing	Bogus routing information, selective forwarding, sinkholes, Sybil, wormholes, HELLO floods
Directed diffusion and multipath variant	Bogus routing information, selective forwarding, sinkholes, Sybil, wormholes, HELLO floods
Geographic routing (GPSR,GEAR)	Bogus routing information, selective forwarding, Sybil
Minimum cost forwarding	Bogus routing information, selective forwarding, sinkholes, wormholes, HELLO floods
Clustering based protocols (LEACH,TEEN,PEGASIS)	Selective forwarding, HELLO floods
Rumor routing	Bogus routing information, selective forwarding, sinkholes, Sybil, wormholes
Energy conserving topology maintenance	Bogus routing information, Sybil, HELLO floods

All are insecure

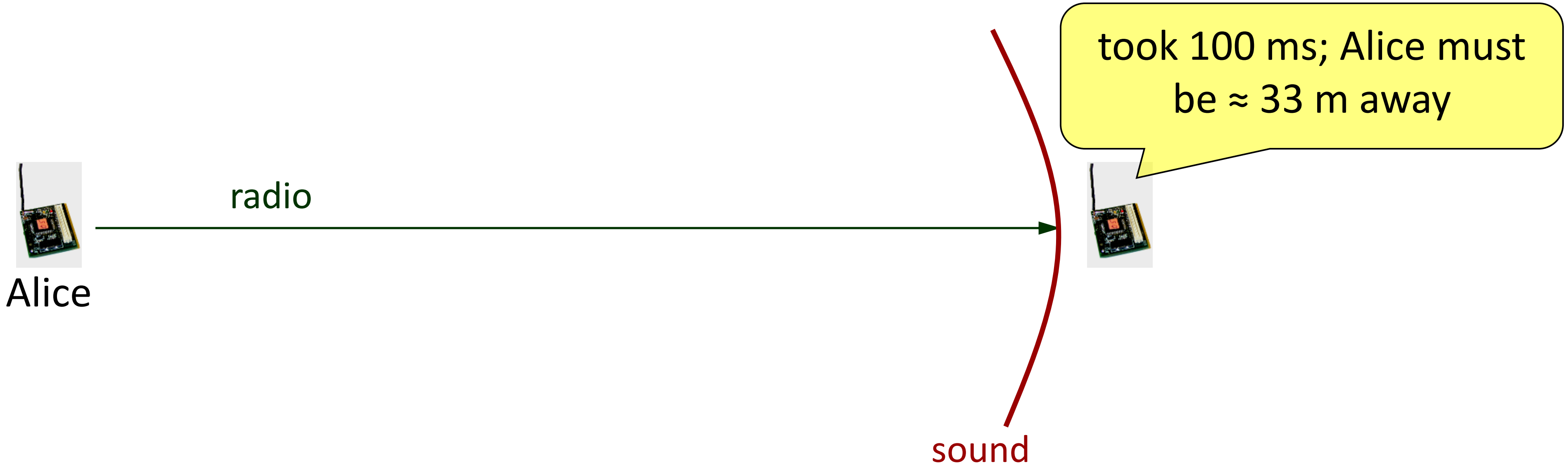
III. Interacting With The Environment: Location Verification

“Where ever you go, there you are.”

Location Determination

How far away is Alice?

- Have her transmit & chirp; measure elapsed time

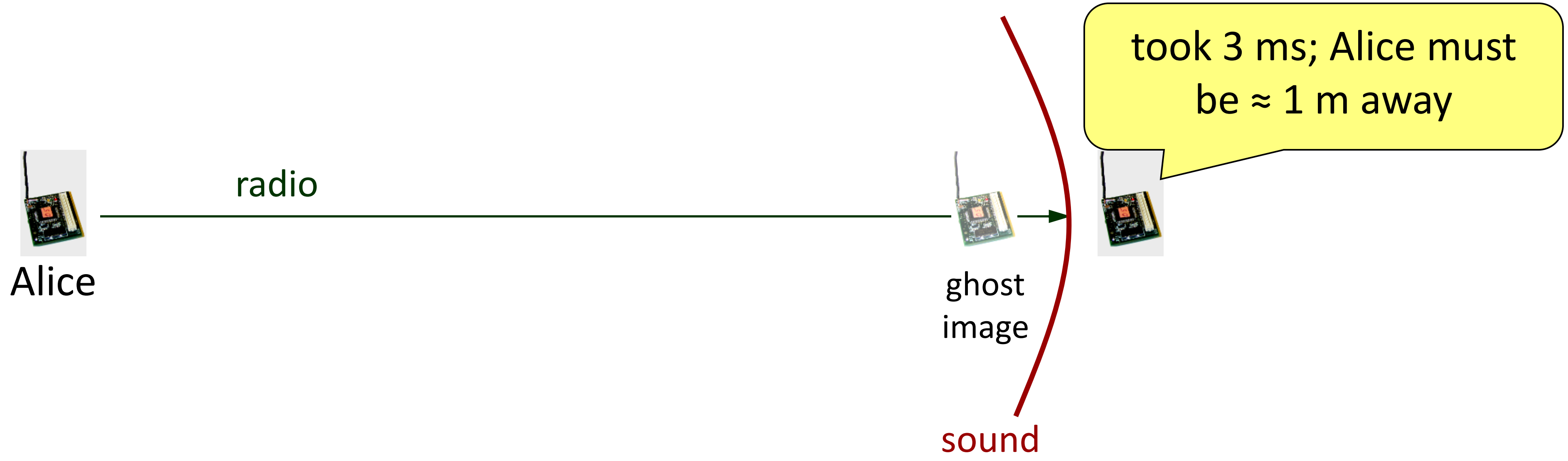


The Ventriloquist Attack

Alice is malicious; she wants to seem nearby

- Attack: Chirp in advance, wait a little, then transmit

Effect: Alice is able to lie about her location.



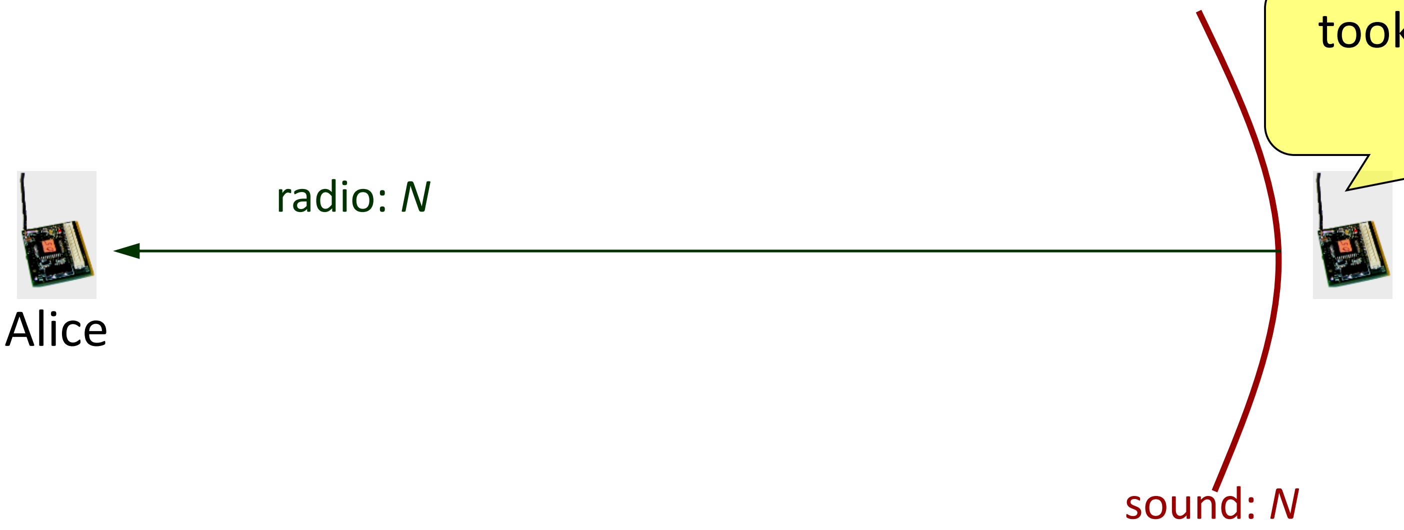
The Echo Protocol

Secure location verification

- Add a challenge-response, and Alice can't chirp early

Result: Alice can no longer lie about her location.

took 100 ms; Alice must be ≥33 m away



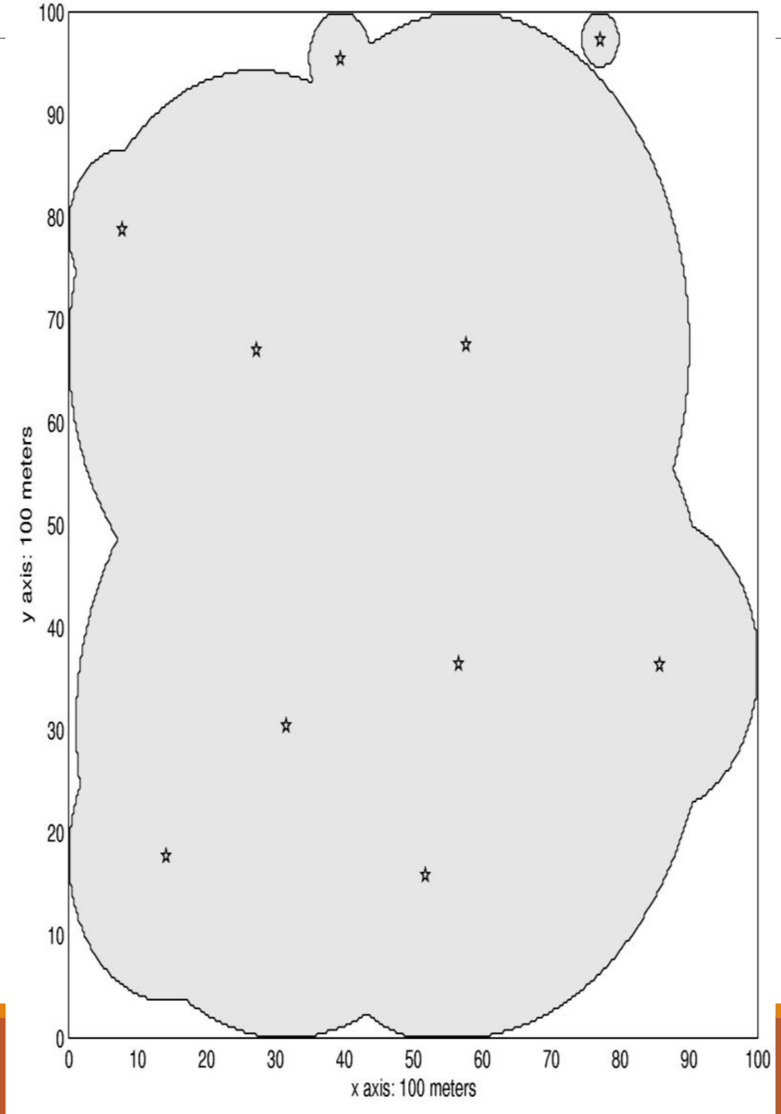
Protocol:

1. V→A: *N*
2. A→V: *N*

Secure Location Services

For more details: see the Echo protocol [SSW03], a secure protocol for location verification

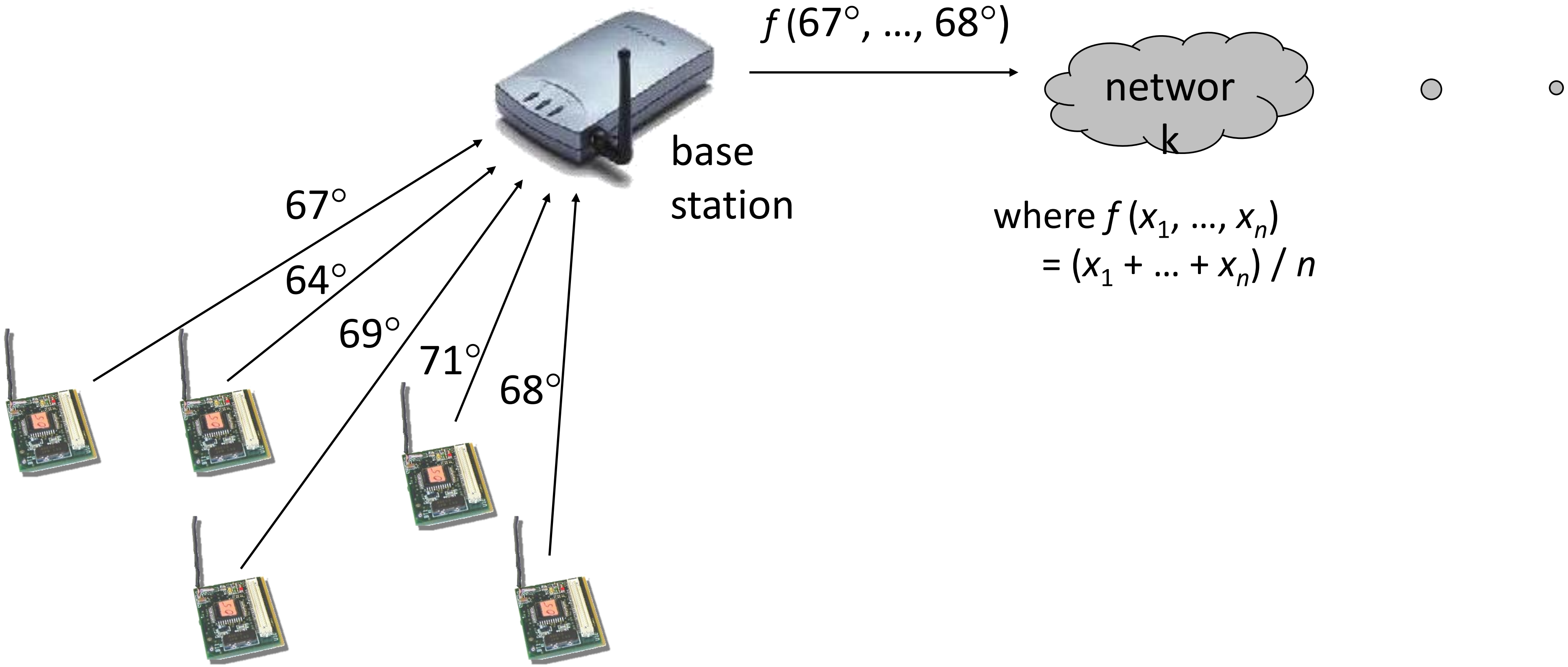
Applications: location-based access control



IV. Tolerating Malicious Data: Resilient Aggregation

"If you believe that, I have a bridge to sell."

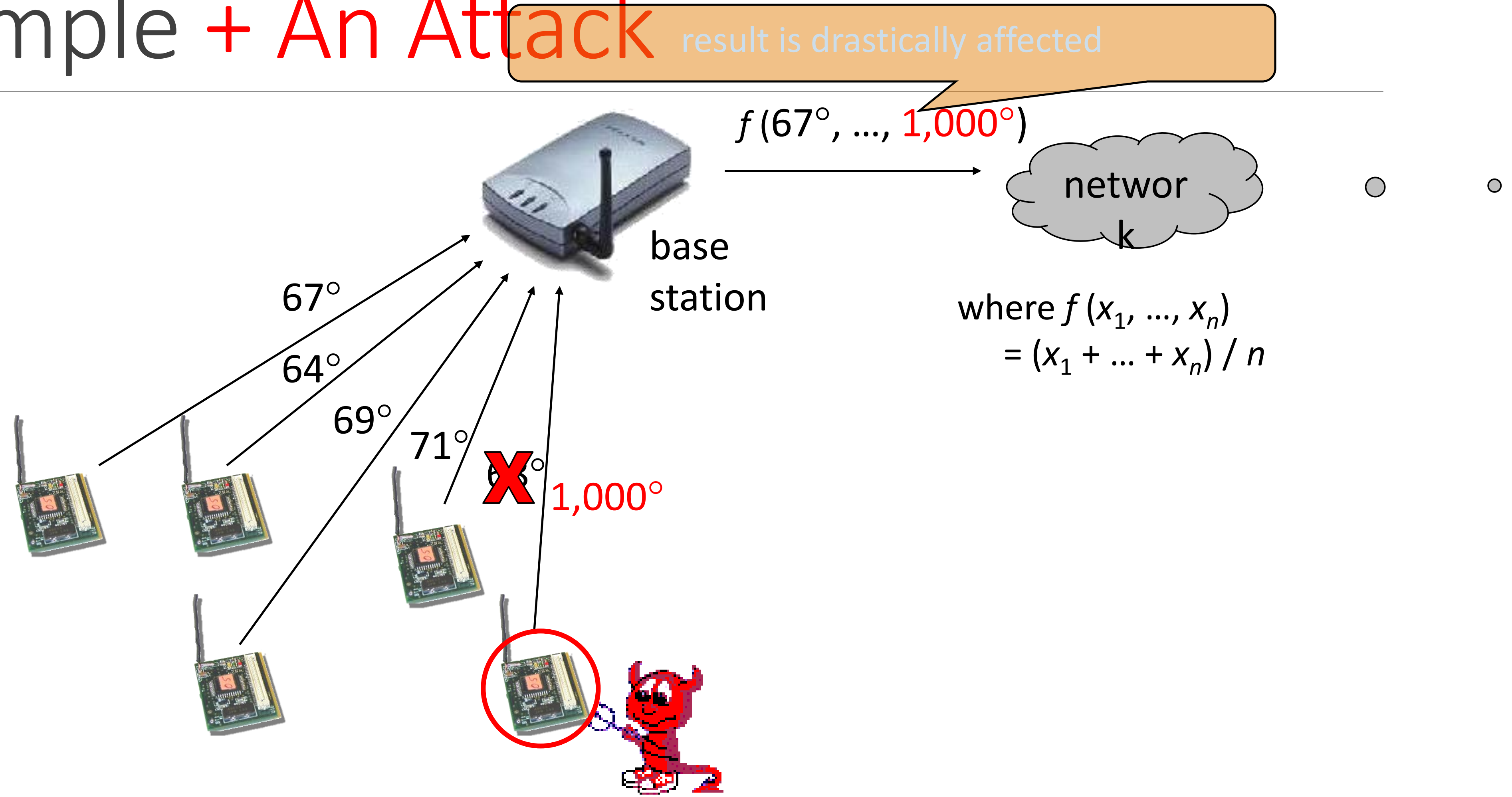
An Example



where $f\,(x_1, \ldots, x_n)$
$= (x_1 + \ldots + x_n) / n$

Computing the average temperature

An Example + An Attack



Computing the average temperature

Statistical Theory

First, some background:

- Let $D(\Theta)$ be a parametrized distribution on $\Re$ (Θ = param),
  $X = (X_1, \ldots, X_n)$ denotes n samples from $D(\Theta)$
- $f : \Re^n \rightarrow \Re$ is an *estimator* if $\Theta' = f(X)$ is an estimate of Θ
- The *root mean square error* of an estimator f is
  $\mathrm{rms}(0) = E[(\Theta' - \Theta)^2]^{1/2}$

Next, a novel defense: resilient aggregation

- A k-node attacker A is a function $A: \Re^n \rightarrow \Re^n$ that changes only k of its inputs. Let $\Theta^* = f(A(X))$, $\mathrm{rms}(k) = \max_A E[(\Theta^* - \Theta)^2]^{1/2}$
- Definition: f is (k, α)-resilient if $\mathrm{rms}(k) \leq \alpha \times \mathrm{rms}(0)$
- E.g.: the "average" is an estimator, but it is not $(1, \alpha)$-resilient for any constant α

Relevance of Resilience

Intuition

- The (k, α)-resilient functions are exactly the ones that can be meaningfully and securely computed in the presence of k malicious insiders.

Formalism

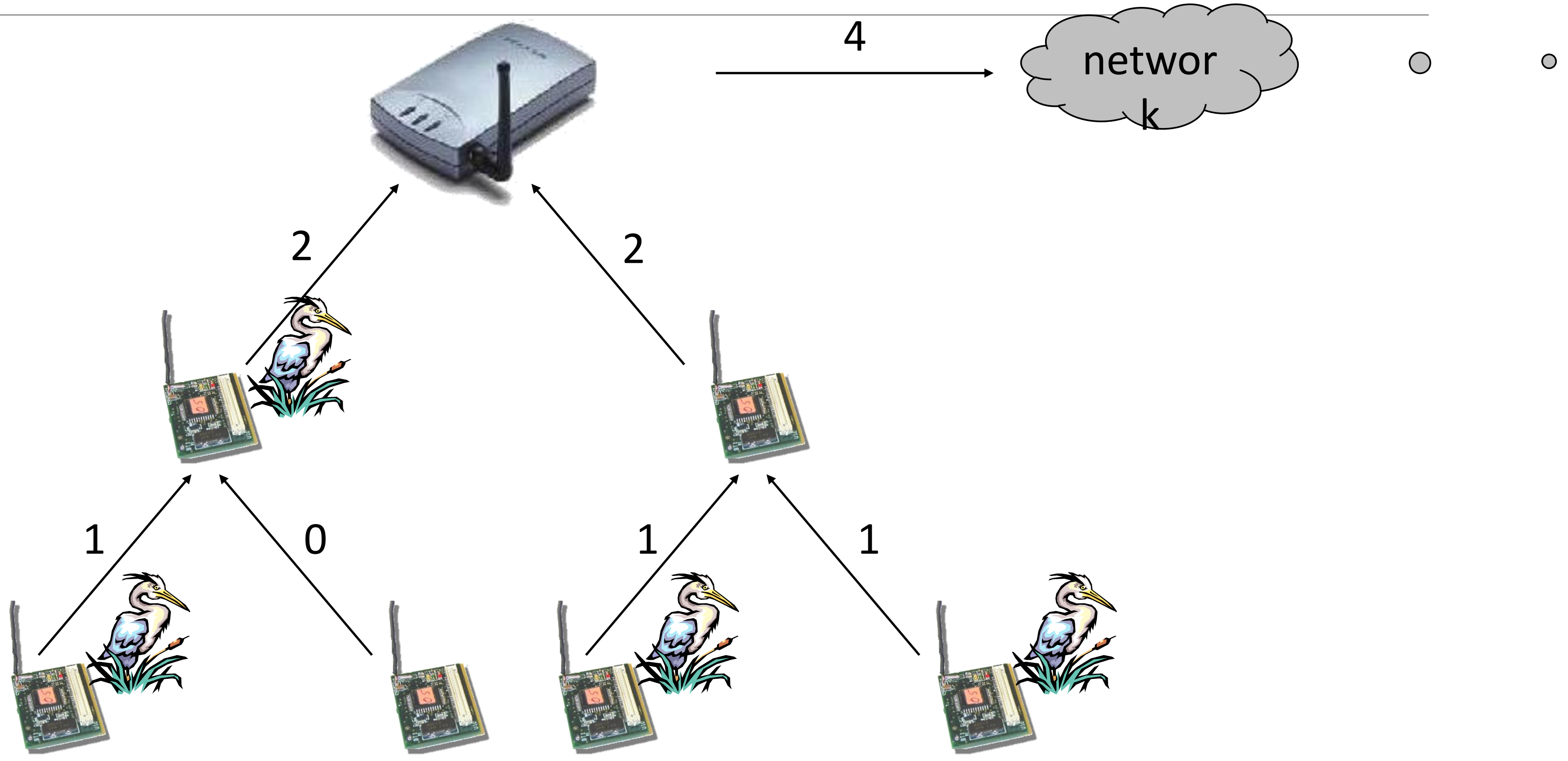
- (see paper)

Results (excerpts)

f	… is (k, α)-resilient, where
minimum	$\alpha = \infty$
maximum	$\alpha = \infty$
sum	$\alpha = \infty$
average	$\alpha = \infty$
average, discarding 5% outliers	$\alpha \approx 6.28\, k/n$ for $k < 0.05\, n$ $\alpha = \infty$ for $k > 0.05\, n$
median	$\alpha \approx 0.32\, k$ for $k < 0.5\, n$
max	$\alpha = \infty$
count	$\alpha \leq 0.25\, k/n$

(assuming *n* independent Gaussian/Bernoulli distributions)

Hard: In-Network Resilient Agg.



In-network aggregation introduces new security challenges

Hard Problems

Communication security

- Defeating traffic analysis; spread spectrum for real?

A library of secure distributed services & protocols

Security against node compromise/capture

- e.g., routing that can tolerate just one malicious insider?
- Byzantine attack tolerance, on the cheap?

Privacy

Summary

Crypto helps, but isn't a total solution

- Be aware of the systems tradeoffs

Seek robustness against insider attack

- Resilience gives a way to think about malicious/captured nodes
- The law of large numbers is your friend

Feedback?

Thank You

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