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An Authentication Framework for Wireless Sensor Networks using Identity-based Signatures

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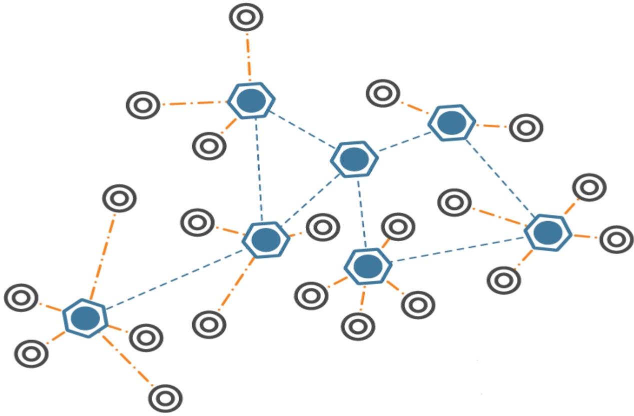
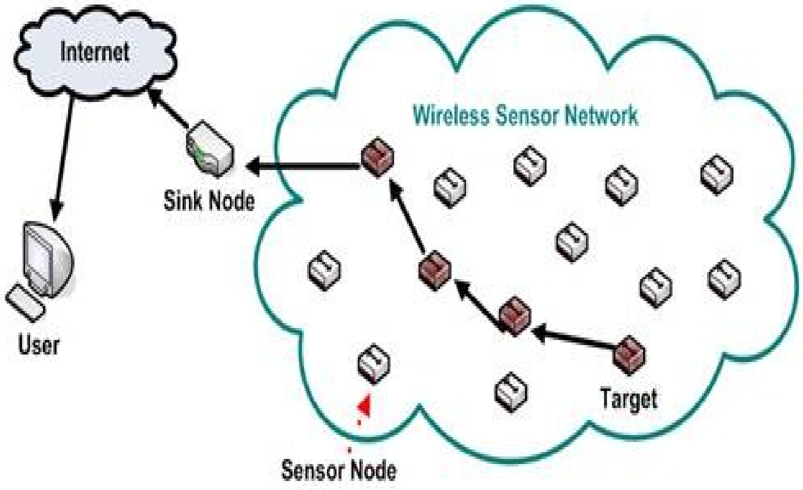


Outline of the Presentation

- Introduction
- Challenges
- Existing Approaches in WSN
- Problem Definition
- Proposed Authentication Framework
- Comparison with Existing Schemes
- Conclusion & Future Work

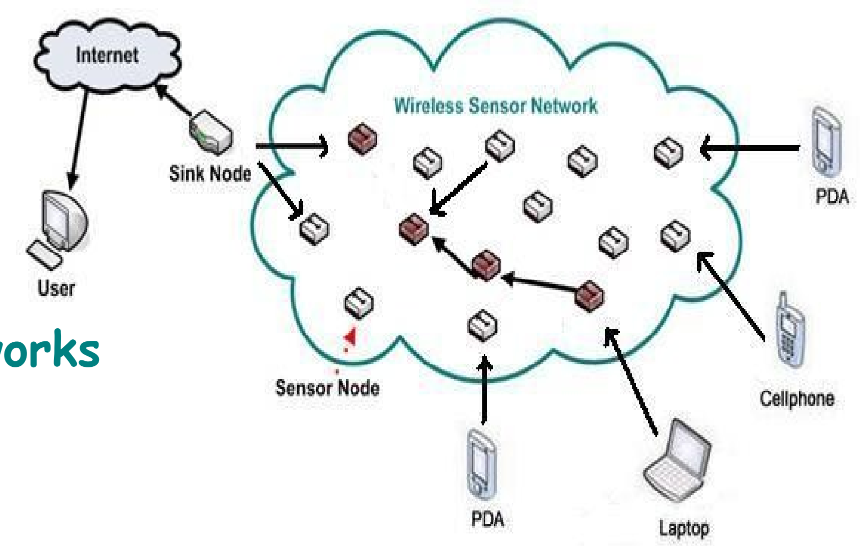
Introduction: Wireless Sensor Networks

- Composed of small low cost resource constrained sensor nodes (motes)
- Monitor and report certain phenomenon
- Adversary can inject false data packets, modify original data packets
- Adversary can also compromise sensor nodes



Introduction: Authentication

- Countermeasure: **Authentication**
  - ❖ Verify claimed message sender
  - ❖ Contents of a message



Authentication in Wireless Sensor Networks

- Base station to sensor nodes
- Sensor node to other sensor nodes
- Outside user to sensor nodes
  - ❖ Session key establishment
  - ❖ Access control enforcement

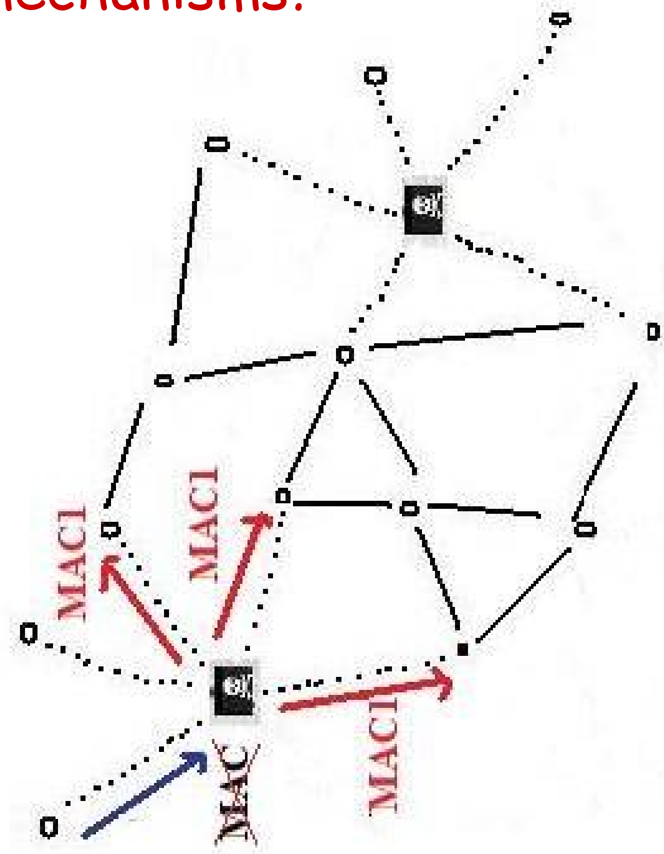
Challenges

Why not use conventional authentication mechanisms?

- Sensor nodes are resource constrained devices
  - Low processing capability
  - Low battery power
  - Low storage
  - Low bandwidth

- Hurdle in applying strong cryptographic based authentication schemes e.g., digital signatures

- Compromised sensor nodes do not allow Message Authentication Code



Existing Approaches: μ-TESLA

[Perrig 2002, Liu 2004 & 2005, Drissi 2006, Gu 2007]

Issues with μ-TESLA based Schemes

- Base station to other sensor nodes authentication
- Sensor node broadcasts through base station only
- Not suitable for real time applications
- Delayed authentication
- Denial of Service (DoS) attack
- Multiple senders broadcast turn by turn during predefined time intervals
- Support only limited number of broadcast senders

Existing Approaches: Digital Signature

[Ren 2007, Cao 2008]

Issues with Digital Signature based Schemes

- Public key and certificate management
    - ❖ Send public key and certificate with every message
        - ❑ Low bandwidth
        - ❑ Two signature verifications per message
    - ❖ Store public key of each sender
        - ❑ Storage overhead
        - ❑ Reduces scalability
    - ❖ User authentication also suffer from the same problem
- Message signing expensive in terms of time and energy consumption

Problem Definition

- Authentication mechanism which provides
  - Broadcast or multicast without the involvement of base station
  - Quick broadcast of real time messages
  - Authentication of messages
  - Authentication of any outside user
- Public key and/or certificates management

Proposed Authentication Framework

- An authentication framework which utilizes

  - ❖ Identity-based signatures

    AND

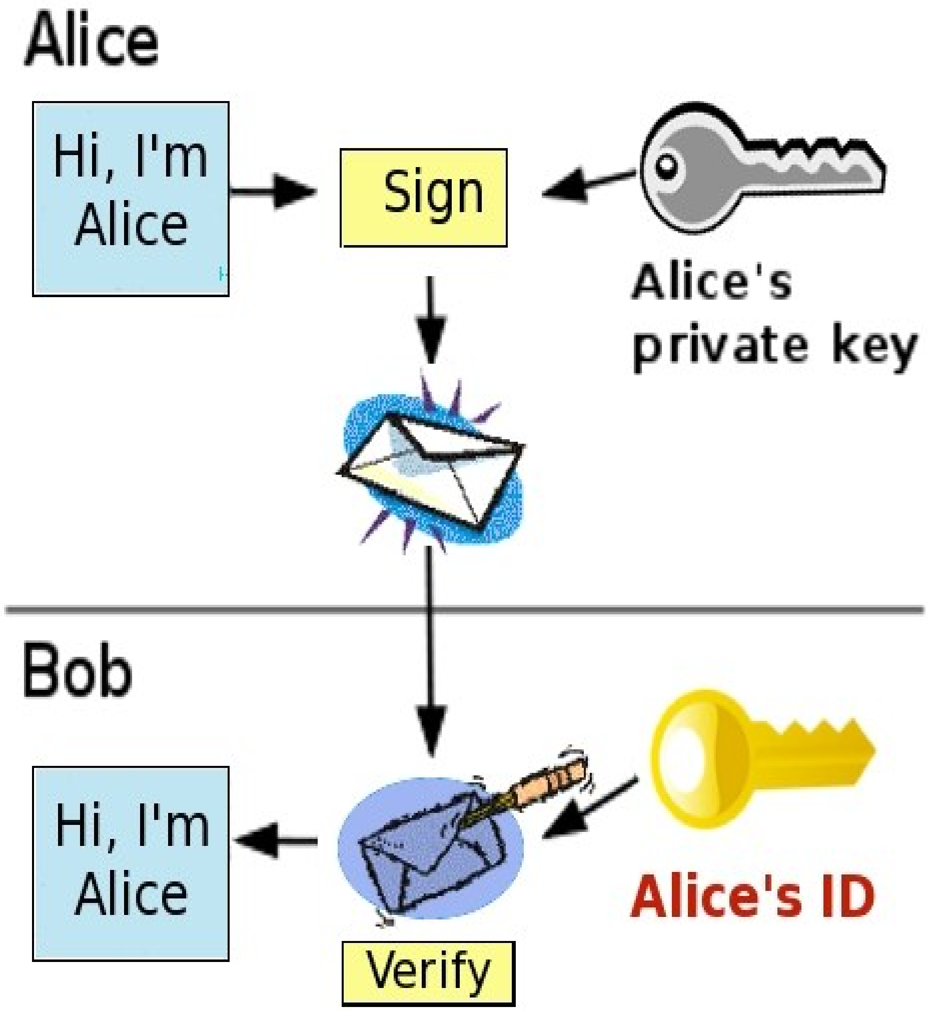
  - ❖ Online/Offline signature schemes

Proposed Authentication Framework

Identity-based Signatures

[Shamir84, …]

- User can use his identity information as his public key
- Corresponding private key generated by a private key generator (PKG)
- Eliminates the need of a certificate



Proposed Authentication Framework

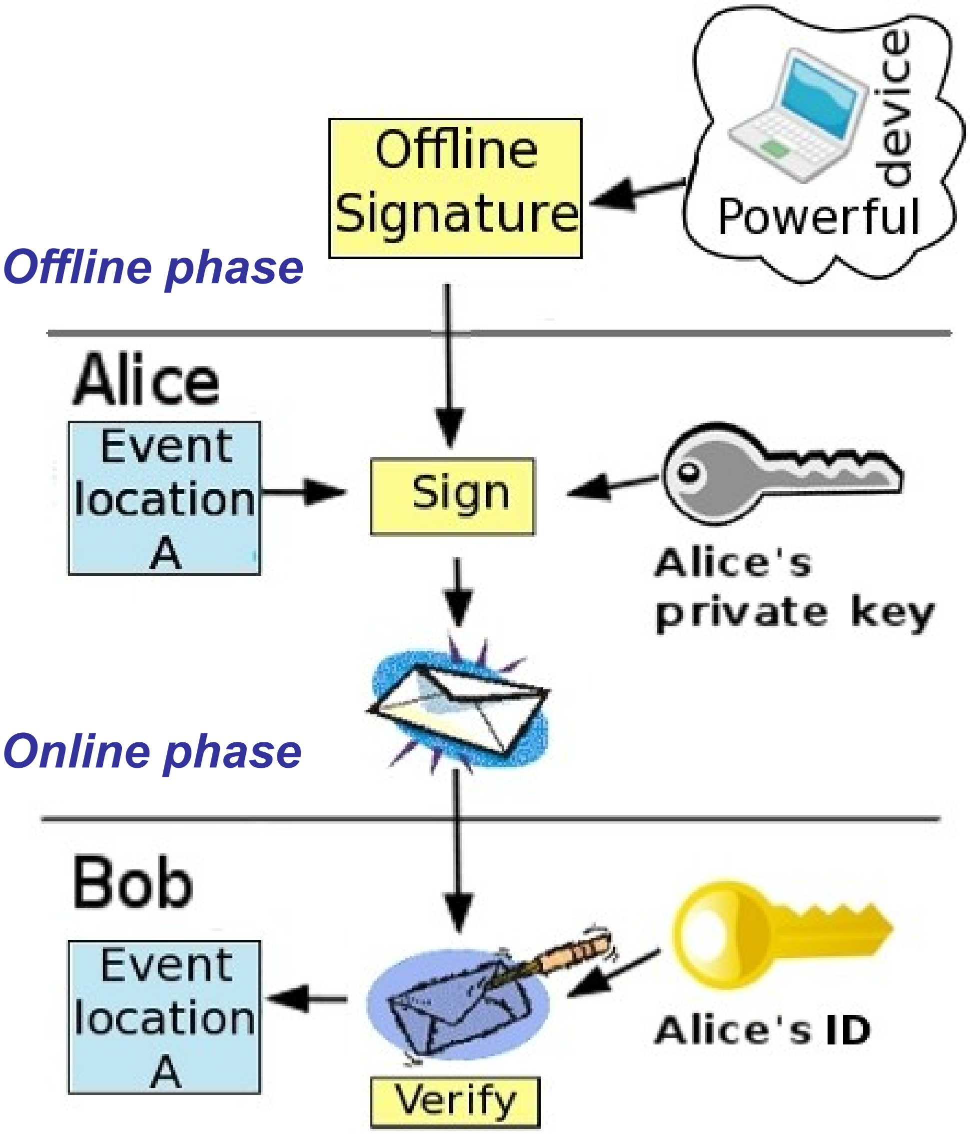
Online/Offline Signatures

[Even 1989, …]

- Message signing is divided into two phases:
  - *Offline* phase
  - *Online* phase

- Offline phase performed by a resourceful device

- Suitable for resource constrained signer



Proposed Authentication Framework

The proposed authentication framework

- Comprised of two authentication schemes
  - ❖ Sensor Broadcast Authentication
  - ❖ Outside User Authentication
- Utilizes
  - ❖ ID-based online/offline signature (IBOOS) for sensor broadcast authentication

AND

  - ❖ ID-based signature (IBS) for outside user authentication

Sensor Broadcast Authentication Scheme

- Base station, a resourceful and trustworthy entity, plays the role of PKG
- First two phases are performed before the deployment

1. System Initialization

- Base station computes:
  - msk SK_{PKG}, mpk PK_{PKG}, system parameters SP

2. Key Generation

- Base station computes:
  - private keys D_{ID} corresponding to user ID
- ID, D_{ID}, PK_{PKG} and SP are stored on sensor nodes before deployment

Sensor Broadcast Authentication Scheme

3. *Message Broadcast*
   - Offline phase: performed on base station (before hand)

     $$S \leftarrow \mathit{OffSign}\,(D_{ID}, SP)$$

   - Online phase: performed on sensor node

     $$s \leftarrow \mathit{OnSign}\,(m, S, TS)$$

4. *Authentication*
   - On receiving a message, sensor node
     - ❖ Verifies time stamp *TS*
     - ❖ Verifies signature using signer's ID and system parameters

       $$0/1 \leftarrow \mathit{Ver}\,(m, ID, s, SP)$$

Outside User Authentication Scheme

- Base station, a resourceful and trustworthy entity, plays the role of PKG

1. *System Initialization*

   Same as in first scheme

2. *Key Generation*

   Same as in first scheme

3. *User Registration*
   - Performed every time when a new user is registered with the system
   - Base station computes:
     - private key D_{ID} corresponding to user ID
   - User U receives ID_U, D_{ID_U}, PK_{PKG} and SP from base station through a secure channel

Outside User Authentication Scheme

4. *User Request*

- User U signs his request and sends to sensor node N

$$U \rightarrow N: \{RM, TS, ID_U, \sigma\}, \text{ where}$$

$$\sigma \leftarrow \mathit{Sign}((RM, TS, ID_U), D_{ID_U})$$

5. *User Authentication*

- On receiving a user request, sensor node
  - ❖ Verifies time stamp TS
  - ❖ Verifies signature using user's ID and system parameters

$$0/1 \leftarrow \mathit{Ver}(m, ID_U, \sigma, SP)$$

Outside User Authentication Scheme

6. *Session Key Establishment*

- We propose to use ID-based one-pass session key establishment protocol
- During authentication phase, user also sends his ephemeral key E_U
- After successful user authentication, sensor node computes session key using E_U
- The only message exchanged is signed by the user, verified by the sensor node
- Designed our own new ID-based one-pass key establishment protocol

Comparison with Existing Schemes

Schemes	Signature Schemes	Energy Cost (Offline) mW	Energy Cost (Online) mW	Computation Time (Online) s	Storage Overhead
Existing Broadcast Authentication Schemes					
CAS [Ren2007]	ECDSA	0	26.96	0.89	-
DAS [Ren2007]	ECDSA	0	26.96	0.89	22N = 1.2MB
IDS [Ren2007]	Pairing based	0	87.09	3.47	-
IMBAS [Cao2008]	BNN	0	72.90	2.43	-
Proposed Sensor Broadcast Authentication Scheme					
Proposed	IBOOS [Ren2008]	φ*	5.62	0.19	-
Proposed	IBOOS [Xu2005]	48.60	ε*	ε*	-

N = 50,000, φ* shows the cost of underlying signature scheme and ε* shows negligible cost

Comparison with Existing Schemes

Schemes	Signature Schemes	Energy Cost (mW)	Verification Time (s)	Storage Overhead (Bytes)	Session Key
Existing User Authentication Schemes					
RRUASN [Benenson2004]	ECDSA	106.84	3.54	0	No
DP^{2}AC [Zhang2009]	RSA	14.05 + TE	0.47 + TT	10*T	No
Proposed User Authentication Scheme					
Proposed	IBS [Cao2008]	72.90	2.43	0	Yes

TE = Transmission Energy

TT = Transmission Time

T = Used Tokens

Importance of Work and Advantages

- First attempt to handle the problem of authenticated broadcast by sensor nodes
- First application of online/offline signature to wireless sensor networks

- Primary advantages of the proposed authentication framework:
  - Reusability
  - Efficiency
  - Public keys and certificates management
  - Scalability

Conclusion & Future Work

- Proposed authentication framework
  - ❖ Efficient in terms of computation time and energy consumption
  - ❖ Solves the problem of public keys and certificates
  - ❖ Provides scalability

- In future,
  - ❖ Implementation on real sensor nodes
  - ❖ Access control

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Existing Approaches

μ-TESLA [Perrig 2002]

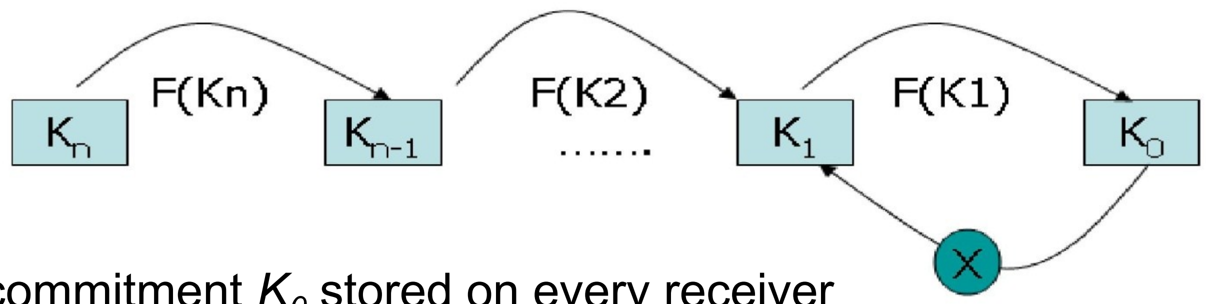
- Micro Timed Efficient Stream Loss-tolerant Authentication
- Message Authentication Code (MAC)
- Symmetric cryptography introduces asymmetry
- Base station to sensor nodes broadcast authentication

Existing Approaches

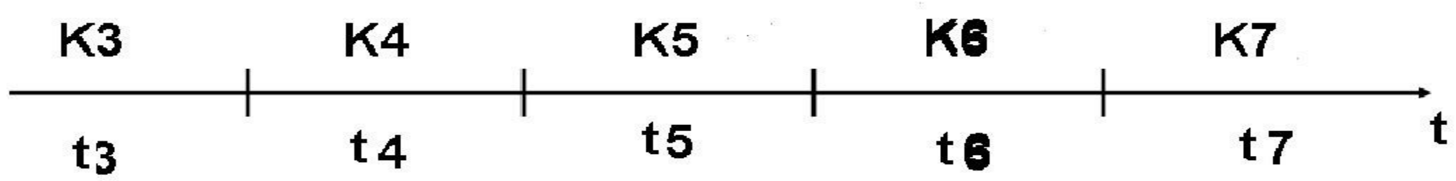
μ-TESLA (continued)

Sender Setup

- One-way hash key chain



- Key commitment K_0 stored on every receiver
- Time divided into n equal parts
- Each key from key chain assigned to one time slot



Existing Approaches

μ-TESLA (continued)

Broadcasting Authenticated Packets

- In time interval i, the sender uses key K_i to compute MAC
- Same MAC key for all packets in that interval
- In time interval $(i + \delta)$, the sender reveals key K_i
- δ depends on round trip time between the sender and the receivers

Existing Approaches

µ-TESLA (continued)

Authenticating Broadcast Packets

- ➢ Sender and receivers need to be loosely time synchronized
- ➢ Receivers need to know the key disclosure schedule
- ➢ A packet verification involves three steps
  - ❖ First, to see if packet is safe
  - ❖ Second, to verify the received MAC key
  - ❖ Third, to verify MAC using verified MAC key