Light Weight Key Establishment Scheme for Wireless Sensor Networks

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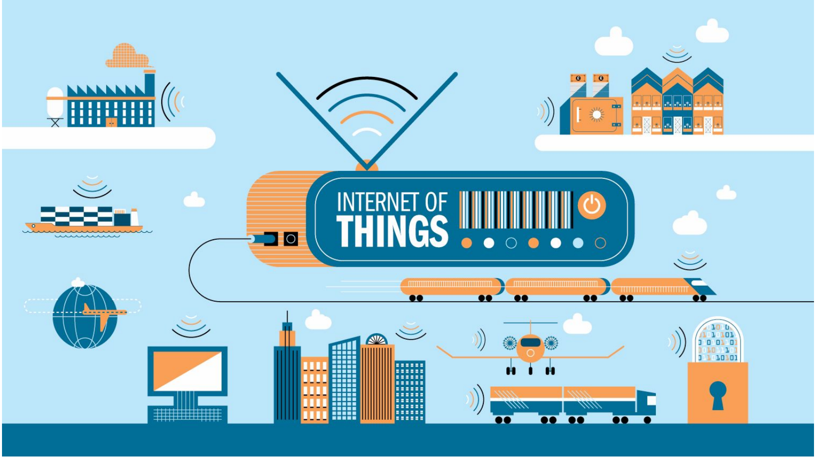
Overview

- Introduction
- Challenges and Goals
- Basic approaches
- Proposed method
- Performance evaluation
- Conclusion
- References

Introduction (1/2)



- IoT is now becoming “the infrastructure of the information society”

Introduction (2/2)

- The rapid advancements in IoT technologies has led to the deployment of wireless sensor nodes in a variety of applications
- Applications of WSNs
  - Industry automation
  - Health care
  - Military surveillance
- Need to provide confidentiality and authenticity to these sensitive data
- Uses symmetric key algorithms to secure data
- Demands secure and reliable key exchange protocols

Key Establishment Schemes in WSNs

Challenges

- Deployment in hostile environments cause increased vulnerability to attacks
- Resource constrained nature of sensor nodes hinders the use of conventional key distribution schemes

Goals

- Should provide security against eavesdropping
- Should prevent unauthorised nodes from establishing communication with network nodes
- Should ensure connectivity
- Should support node addition

Evaluation Metrics

Efficiency

- Storage efficiency
- Computational cost
- Communication overhead
- Connectivity

Flexibility

- Scalability
- Dependence on deployment knowledge

Security

- Resilience
- Eavesdropping
- Hello flood attack
- Node addition attack
- Node cloning attack

Basic Approaches[1] (1/4)

Global key

- ✓ Single master key
- ✓ Best in terms of efficiency
- ✓ Compromise of any one node reveals the secret key of the entire network

Full pair wise key

- ✓ Each node receives pair wise keys to communicate with every other node in the network
- ✓ High resilience and connectivity
- ✓ Lack of scalability

[1] M.A. Simplcio, P.S. Barreto et.al," A survey on key management mechanisms for distributed wireless sensor networks". *Computer Networks*, vol. 54, no.15, 2010, pp. 2591-2612.

Basic approaches (2/4)

Random key pre-distribution[2]

- ✓ Generate a key pool of size p
- ✓ Load each node with a key ring composed of r keys randomly chosen from the key pool($r < p$)
- ✓ If any two neighbouring nodes share secret key, then a secure link is established
- ✓ Value of r and p determines the connectivity and security of the network

Polynomial based key management[3]

- ✓ A bi-variate, λ degree polynomial over a prime field is loaded in to each sensor node
- ✓ The polynomial is used to generate secret keys
- ✓ Network is secure as long as λ or less nodes are compromised

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[2] L. Eschenauer and V. D. Gligor, A key management scheme for distributed sensor networks, in *Proc. 9th ACM Conf. Comput. Commun. Security*, 2002, pp. 41-47.

[3] D.Liu, P. Ning, R. Li, "Establishing pairwise keys in distributed sensor networks, *ACM Transactions on Information and System Security (TISSEC)* vol.8, no.1, pp. 41-77.

Basic approaches (3/4)

Key management based on transitory master key [4]

- ✓ Master key is used in the initialization phase for authentication and secret key establishment.
- ✓ The master key is erased after a time-out period
- ✓ Time-out represents a trade-off between connectivity and security

Key management based on hard mathematical problems

- ✓ ECC, Modular arithmetic
- ✓ Highly secure even if nodes are compromised in the initialization phase
- ✓ Computationally intensive and less energy efficient

[4] F. Gandino, B. Montrucchio, M.Rebaudengo, "Key management for static wireless sensor networks with node adding", *IEEE Trans. on Industrial Informatics*, vol. 10, no.2, pp. 1133-1143, July 2014.

Basic approaches (4/4)

Over-the-air key establishment[5]

- Energy efficiency is increased by reducing the computations
- Secret keys generated through a single hash computation
- Method 1: Extract secret keys from received signal strength
  - Communicating channel must be highly dynamic in nature
- Method 2: Leverage channel anonymity for generating secret keys
  - Assumes adversary to be a passive eavesdropper

Requirement: Energy efficient, deterministic and secure protocol

[5] P. Barsocchi, G. Oligeri, and C. Soriente, "Shake: Single hash key establishment for resource constrained devices," *Ad Hoc Networks*, vol. 11, no. 1, pp. 288-297,2013.

Energy Efficient Protocols

Crypto-less Over-the-air-Key Establishment(COKE)[6]

- Based on source indistinguishability of anonymous channels
- Requires a single hash computation
- Probabilistic, not secure against active adversaries

LEAP+[7]

- Based on transitory master key
- Offers zero resilience if a node is compromised in the initialization phase
- Prone to jamming attacks

[6] R. Di Pietro and G. Oligeri, COKE crypto-less over-the-air key establishment," *IEEE Trans. on Information Forensics and Security*, vol. 8, no. 1, pp. 163-173, 2013.

[7] S. Zhu, S. Setia, and S. Jajodia, LEAP+: Efficient security mechanisms for large-scale distributed sensor networks," *ACM Transactions on Sensor Networks (TOSN)*, vol. 2, no. 4, pp. 500-528, 2006

Proposed Method (1/2)

Assumptions

- Homogeneous
- Static
- Supports node addition
- Eavesdropper can listen to all the traffic in the network

Data loaded into the sensor node prior to deployment

- Master key (MK)
- Random integer n_i
- Node identifier ID_i

Proposed Method (2/2)

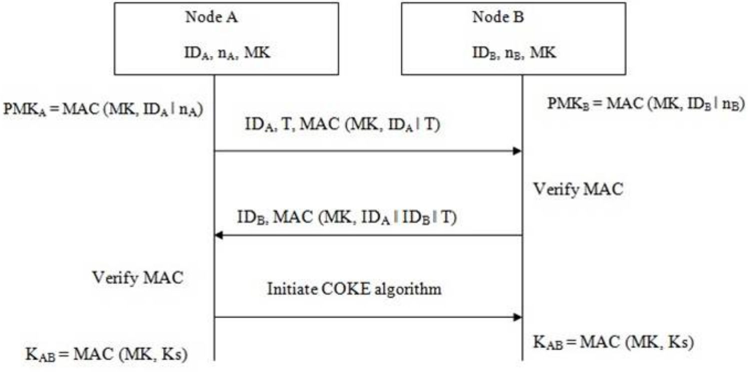

Figure: Proposed key establishment scheme

Security Metric (1/4)

Resilience

Probability that a link between uncompromised nodes is not compromised due to other compromised nodes in the network.

- In the proposed method, key in any link depends upon random data exchanged between the node pair through COKE algorithm.
- Data available to the attacker if a node is compromised
  - MK / PMK
  - Node ID
  - Pair wise secret key with the neighbouring nodes
- Not sufficient to compromise any other link
- Offers high resilience even if nodes are compromised in the initialization phase

Security Metric (2/4)

Hello flood attack

Adversary sends hello messages to the neighbouring nodes with high transmission power

- Hello messages in the proposed scheme consists of an authentication tag generated using the master key
- COKE algorithm is initiated only after successful MAC verification
- Defends Hello Flood attack because only authenticated hello messages are processed by the node

Security Metric (3/4)

Node cloning / Node replication

Adversary loads its own nodes with the compromised information and tries to establish pair-wise keys with the valid nodes.

- Probability that a single key is shared by more than one link is negligibly small
- Establishment of new pair wise keys demands the knowledge of MK
- Resists Node cloning / Node replication attack

Security Metric(4/4)

Node addition attack

Adversary introduces new nodes into the network by loading it with the correct master key.

- Node id's are randomly generated by the base station
- Base station broadcasts a list of valid node ids added in each phase
- Nodes verify their neighbour's ids before initiating secret key establishment.
- Less prone to node addition attack.

Efficiency Metric (1/2)

Computational cost

Two MAC computations at each node for every pair-wise key establishment

Connectivity

Deterministic protocol - secret key is established between every authenticated neighbouring node

Storage requirement

- Initialization phase : node ID, MK, random integer
- Working phase : PMK, node ID, shared secret keys

Efficiency Metric (2/2)

Communication overhead

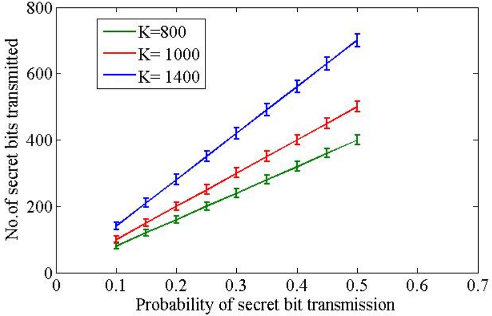

Figure: Number of secret bits transmitted for different values of K[8]

[8] K: Total number of bits transmitted

Table: Overall Comparison

	Proposed scheme	LEAP+	COKE
Storage (in bytes)	738	738	722
Communication overhead (in bytes)	120	36	175
Prob. of eavesdropping a link with nodes compromised in the working phase	0	0	0
Prob. of eavesdropping a link with nodes compromised in the initialization phase	0	1	0
Prob. of node addition attack	0	0	1
Scalability support	YES	YES	YES

Conclusion

- Developed an energy efficient, secure and deterministic key establishment technique for WSNs.
- Combined concepts of transitory master key and over-the-air key establishment
- Compared to COKE, the proposed scheme is secure against active adversaries
- Compared to LEAP, offers high resilience even if nodes are compromised in the initialization phase

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THANK YOU