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An Analytical study on Key Pre-distribution in Wireless Sensor Networks.

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Abstract:

A wireless sensor network (WSN) of spatially distributed autonomous sensors to monitor physical or environmental conditions, such as temperature, sound, pressure, etc. and to cooperatively pass their data through the network to a main location. Wireless sensor networks are installed in a lot of intimidating and unfriendly atmospheres and countenance numerous security issues.

Sensor nodes are also resource-constrained. Given the sensitivity of the potential WSN applications and because of resource limitations, key management emerges as a challenging issue for WSNs.

One of the main concerns when designing a key management scheme is the network scalability. Indeed, the protocol should support a large number of nodes to enable a large scale deployment of the network. In this paper, we propose a new scalable key management scheme for WSNs which provides a good secure connectivity coverage. For this purpose, we make use of the unital design theory.

To attain security in wireless sensor networks, many key management methods have been proposed in the past. In this research paper we aspire to study these key distribution. In this paper we proposed a scheme which is scalable and requires less number of keys for a given number of nodes than the existing well known methods.

Our results show that the proposed approach enhances the network scalability while providing high secure connectivity coverage and overall improved performance. Moreover, for an equal network size, our solution reduces significantly the storage overhead compared to those of existing solutions.

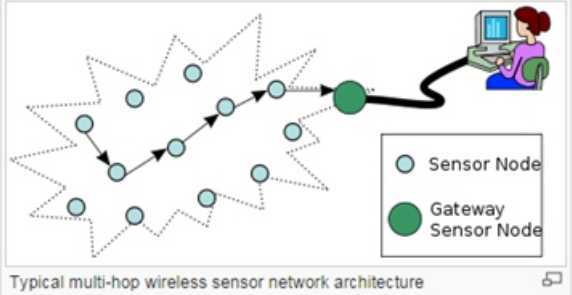
Keywords:

Wireless, Keys, Cryptography, Embedded systems, communications.

Introduction:

The WSN is built of "nodes" – from a few to several hundreds or even thousands, where each node is connected to one (or sometimes several) sensors. Each such sensor network node has typically several parts: a radio transceiver with an internal antenna or connection to an external antenna, a microcontroller, an electronic circuit for interfacing with the sensors and an energy source, usually a battery or an embedded form of energy harvesting.

A sensor node might vary in size from that of a shoebox down to the size of a grain of dust, although functioning "motes" of genuine microscopic dimensions have yet to be created. The cost of sensor nodes is similarly variable, ranging from a few to hundreds of dollars, depending on the complexity of the individual sensor nodes. Size and cost constraints on sensor nodes result in corresponding constraints on resources such as energy, memory, computational speed and communications bandwidth. The topology of the WSNs can vary from a simple star network to an advanced multi-hop wireless mesh network. The propagation technique between the hops of the network can be routing or flooding.



Typical multi-hop wireless sensor network architecture

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Nowadays, wireless sensor networks (WSNs) are increasingly used in critical applications within several fields including military, medical and industrial sectors. Given the sensitivity of these applications, sophisticated security services are required. Key management is a corner stone for many security services such as confidentiality and authentication which are required to secure communications in WSNs.

The establishment of secure links between nodes is then a challenging problem in WSNs. Because of resource limitations, symmetric key establishment is one of the most suitable paradigms for securing exchanges in WSNs. On the other hand, because of the lack of infrastructure in WSNs, we have usually no trusted third party which can attribute pairwise secret keys to neighboring nodes, that is why most existing solutions are based on key pre-distribution.

Over the last decade, a host of research work dealt with symmetric key pre-distribution issue for WSNs and many solutions have been proposed in the literature. Nevertheless, in most existing solutions, the design of key rings (blocks of keys) is strongly related to the network size, these solutions either suffer from low scalability (number of supported nodes), or degrade other performance metrics including secure connectivity, storage overhead and resiliency in the case of large networks.

In this work, our aim is to tackle the scalability issue without degrading the other network performance metrics. For this purpose, we target the design of a scheme which ensures a good secure coverage of large scale networks with a low key storage overhead and a good network resiliency.

The key establishment mechanism employed in a given sensor network should meet many requirements to be efficient. These requirements may include supporting in network processing and facilitating self-organization of data, among others. However, the key establishment technique for a secure application must minimally incorporate authenticity, confidentiality, integrity, scalability, and flexibility.

- **Authenticity:**

The key establishment technique should guarantee that the communication nodes in the network have a way for verifying the authenticity of the other nodes involved in a communication, i.e., the receiver node should recognize the assigned ID of the sender node.

- **Confidentiality:**

The key establishment technique should protect the disclosure of data from unauthorized parties. An adversary may try to attack a sensor network by acquiring the secret keys to obtain data. A better key technique controls the compromised nodes to keep data from being further revealed.

- **Integrity:**

Integrity means no data falsification during transmissions. Here in terms of key establishment techniques, the meanings are explained as follows. Only the nodes in the network should have access to the keys and only an assigned base station should privilege to change the keys. This would effectively prevent unauthorized nodes from obtaining knowledge about the keys used and preclude updates from external sources.

- **Scalability:**

Efficiency demands that sensor networks utilize a scalable key establishment technique to allow for the variations in size typical of such a network. Key establishment techniques employed should provide high-security features for small networks, but also maintain these characteristics when applied to larger ones.

- **Flexibility:**

Key establishment techniques should be able to function well in any kind of environments and support dynamic deployment of nodes, i.e., a key establishment technique should be useful in multiple applications and allow for adding nodes at any time.

Symmetric key establishment is then one of the most suitable paradigms for securing exchanges in wireless sensor networks. Because of the lack of infrastructure in Wireless sensor networks, we have usually no trusted third party which can attributePair wise secret keys to neighboring nodes that is why most existing solutions are based on key pre-distribution.

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Key establishment process in Wireless sensor networks mainly consists of three phases.

1. Key pre-distribution : Pre-loading keys in sensor nodes prior to deployment. The keys present in a sensor node constitute the key ring of the sensor.

2. Shared key discovery : To find a common shared key between two communicating nodes.

3. Path key establishment : If a common key does not exists, then a path has to be found between the communicating nodes. A path key is then established between the communicating nodes.

Existing System:

Wireless sensor networks (WSNs) are increasingly used in critical applications within several fields including military, medical and industrial sectors. Given the sensitivity of these applications, sophisticated security services are required. Key management is a corner stone for many security services such as confidentiality and authentication which are required to secure communications in WSNs.

The establishment of secure links between nodes is then a challenging problem in WSNs. Because of resource limitations, symmetric key establishment is one of the most suitable paradigms for securing exchanges in WSNs.

On the other hand, because of the lack of infrastructure in WSNs, we have usually no trusted third party which can attribute pair wise secret keys to neighboring nodes, that is why most existing solutions are based on key pre-distribution.

Disadvantages of Existing System:

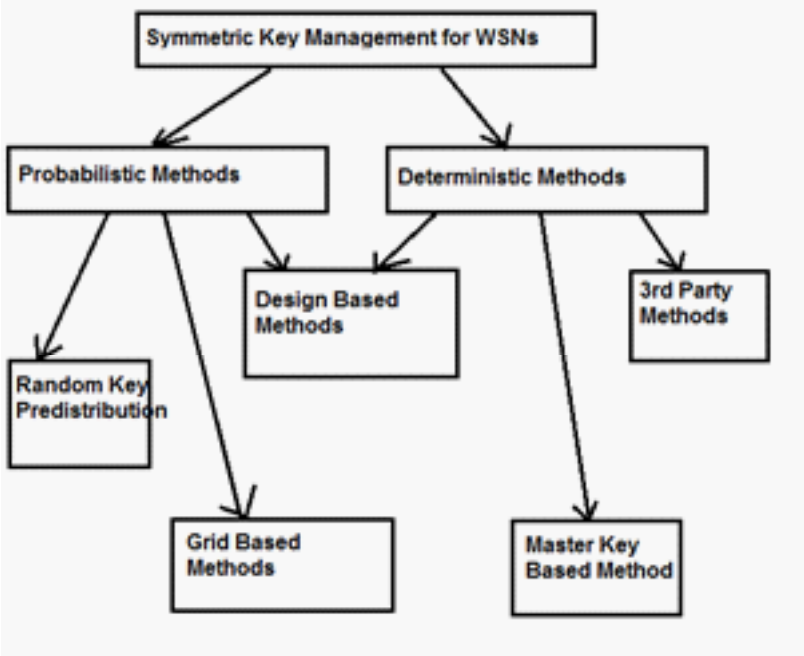
A host of research work dealt with symmetric key predistribution issue for WSNs and many solutions have been proposed In the existing system many disadvantages occur:

the design of key rings (blocks of keys) is strongly related to the network size, these solutions either suffer from low scalability (number of supported nodes), or degrade other performance metrics including secure connectivity, storage overhead and resiliency in the case of large networks.

Proposed System:

In this proposed system, our aim is to tackle the scalability issue without degrading the other network performance metrics. For this purpose, we target the design of a scheme which ensures a good secure coverage of large scale networks with a low key storage overhead and a good network resiliency. To this end, we make use, of the unital design theory for efficient WSN key pre-distribution.

Architecture:



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The proposed algorithm a random block distribution allowing to pre-load t disjoint blocks in each sensor node. Generate B =< Bq >, key sets corresponding to blocks of a unital design of order m

```
For each Node i do
        KRi = {}
        While (|KRi| ≤ t (m + 1)) do
                Pick Bq from B
                If ((KRi ∩ Bq) =Ø) then
                KRi = KRi U Bq
                B = B − Bq
                End
        End
End
```

Algorithm: A random approach of unital block pre Distribution in the enhanced unital-based scheme

Advantages of Proposed System:

The advantages of the proposed system as follows:

1.We propose a naive mapping from unital design to key pre-distribution and we show through analytical analysis that it allows to achieve high scalability.

2.We propose an enhanced unitalbased key pre-distribution scheme that maintains a good key sharing probability while enhancing the network scalability.

3.We analyze and compare our new approach against main existing schemes, with respect to different criteria: storage overhead, energy consumption, network scalability, secure connectivity coverage, average secure path length and network resiliency.

Module Description:

After careful analysis the system has been identified to have the following modules:

1. Unital design for key pre-distribution in WSNS:

WSNs are highly resource constrained. In particular, they suffer from reduced storage capacity. Therefore, it is essential to design smart techniques to build blocks of keys that will be embedded on the nodes to secure the network links.

Nonetheless, in most existing solutions, the design of key rings (blocks of keys) is strongly related to the network size, these solutions either suffer from low scalability, or degrade other performance metrics including secure connectivity and storage overhead.

This motivates the use of unital design theory that allows a smart building of blocks with unique features that allow to cope with the scalability and connectivity issues. In what follows, we start by providing the definition and the features of unital design theory. We explain then the basic mapping from unital to key predistribution and evaluate its performance metrics. We propose finally an enhanced unital-based scheme which achieves a good trade-off between scalability and connectivity.

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2. A new scalable unital-based key pre-distribution scheme for WSNS:

In this section, we present a new unital-based key pre-distribution scheme for WSNs. In order to enhance the key sharing probability while maintaining high network scalability, we propose to build the unital design blocks and pre-load each node with a number of blocks picked in a selective way.

A. Key Pre-distribution:

Before the deployment step, we generate blocks of m order unital design, where each block corresponds to a key set. We pre-load then each node with t completely disjoint blocks where t is a protocol parameter that we will discuss later in this section. In lemma 1, we demonstrate the condition of existence of such t completely disjoint blocks among the unital blocks. In the basic approach each node is pre-loaded with only one unital block and we proved that each two nodes share at most one key.

Contrary to this, pre-loading each two nodes with t disjoint unital blocks means that each two nodes share between zero and t2 keys since each two unitals blocks share at most one element. After the deployment step, each two neighbors exchange the identifiers of their keys in order to determine the common keys. If two neighboring nodes share one or more keys, we propose to compute the pairwise secret key as the hash of all their common keys concatenated to each other. The used hash function may be SHA-1 for instance.

This approach enhances the network resiliency since the attacker have to compromise more overlap keys to break a secure link. Otherwise, when neighbors do not share any key, they should find a secure path composed of successive secure links. The major advantage of this approach is the improvement of the key sharing probability.

As we will prove in next subsection, this approach allows to achieve a high secure connectivity coverage since each node is pre-loaded with t disjoint blocks. Moreover, this approach gives good network resiliency through the composite pairwise secret keys which reinforces secure links.

In addition, we show that our solution maintains a high network scalability compared to existing solutions although it remains lower than that of the naïve version.To analyze the performance of our proposed scheme, we introduced the following parameters as a performance metrics.

1. Evolution Metrics:

To represent desirable characteristics in a key-setup scheme for sensor networks we present the following criteria:

Connectivity:

We use global connectivity to refer to the ratio of the number of nodes in the largest isolated component in the final key- sharing graph to the size of the whole network. If the ratio equals 99%, it means that 99% of the sensor nodes are connected, and the rest 1% are unreachable from the largest isolated component. So, the global connectivity metric indicates the percentage of nodes that are wasted because of their unreachability.

Communication overhead:

Since the probability that two neighboring nodes share a key is less than one, when the two neighboring nodes are not connected directly they need to find a route in the key-sharing graph to connect to each other. We need to determine the number of hops required on this route.

2.System Configuration:

In our analysis and simulations, we use the following setup:

- The size of the key pool = 100 000.
- The number of sensor nodes in the sensor network is 10 000.
- The deployment area is 1000 × 1000 .
- The area is divided into a grid of size 100 =10 × 10, with each grid cell of size 100 × 100 .

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• The center of each grid cell is the deployment point.

• The wireless communication range for each node is =40m.

3.Local Connectivity:

We calculate the local connectivity as the probability of two neighboring nodes being able to find a common key.

4.Global Connectivity:

It is possible that the key-sharing in our scheme has a high local connectivity, but we have isolated components. Since those components are disconnected, no secure links can be established among them.

Therefore, it is important to understand whether will have too many isolated components.

Conclusion and future work:

In this work We have proposed a key pre-distribution mechanism with the help of BCH coding. We have got some better resiliency than some of the existing schemes. In future research can be done in order to find a suitable coding scheme which can increase the resiliency of the network.

A coding technique can be found out with large number of code words and large minimum distance so that it can be fitted to key pre-distribution.

Except combinatorial designs, other designs like packing designs, cover free families and many more unexploited designs can be exploited. In our work we have concentrated on random node capture attack.

We conducted analytical analysis and simulations to compare our new solution to existing ones, the results showed that our approach ensures a high secure coverage of large scale networks while providing good overall performances.

In future research can be done so that selective node capture attack also can be taken care.

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