

EFFICIENT BROADCAST AUTHENTICATION WITH HIGHEST LIFE SPAN IN WIRELESS SENSOR NETWORKS

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Abstract-We consider the problem of Authenticated broadcasting messages in a wireless energy-limited network so as to maximize network lifetime. It enabling the base station to send commands and requests to low- powered sensor nodes in an authentic manner is one of the important challenges for securing wireless sensor networks. X-TESLA is a mechanics, which is considering the problem arising from sleep modes, network failures, idle sessions and DoS attacks. But the problem of power energy should not be considered. The lifetime of the sensor nodes may be ended when the broadcasting process. In proposed system we will implement algorithm namely greedy heuristics with X-TESLA for maximize the life time of the sensor networks. The proposed implementation improves network lifetime significantly when compared with network lifetime using the base greedy heuristics in isolation.

Keywords: *Wireless networks, network life time, Security, broadcast authentication.*

1. INTRODUCTION

Scientific innovation in across-the-board increase network and small sensor devices has led to the development of wireless feeler networks with various applications [1]. Sensor nodes are usually constrained in their computation, communication, storage space, and energy capital for inexpensive reason, but need security functions since they are deployed in unattended or even antagonistic environments. The high risk of substantial attacks and the limited capabilities of sensor nodes make it difficult to apply fixed security techniques to wireless sensor networks, posing new challenges [7]. Authentic broadcast, enabling a base station to send authentic messages to compound sensor nodes, is one of the core challenges [3], while even the broadcast by nodes is an important topic in wireless sensor networks [2], [6], [4]. For the purpose, digital signatures (public key) are not very useful in a resource-limited environment, while naïve use of HMAC

(secret key) do not work either, as node confine can lead to a key compromise.

Battery-operated wireless sensor networks can be there deploy in environment in which it is not practical to recharge/replace the battery of a sensor .Hence, these networks must operate subject to the constraint that the energy available to a sensor isn't replenish able. In other wireless network applications, even though it is possible to refresh a node's array (or top off its energy deliver), it is desirable to operate in an energy frugal manner so as to reduce the need for this renew. With this need to conserve energy in many wireless network applications, a number of authors cover residential energy-efficient algorithms for point-to-point communication, multicasting, and broadcasting. The in general purpose of these algorithms is to also make the most of the lifetime (number of successful communications before first message that cannot be complete) or the ability of the network (amount of data traffic carried by the network over a number of set period of moment). life span maximization is considered for wireless sensor networks.

In the most common model used for authority reduction in wireless transmit, signal power attenuates at the rate a/r^d , where a is a media independent stable, r is the space from the pointer resource, and d is another constant between 2 and 4 [5]. So, for this model, $w(I,J) = w(J,I) = c * r(I,J)^d$, where $r(I,J)$ is the Euclidean distance between nodes I and J and c is a constant. In practice, however, this nice relationship between $w(I,J)$ and $r(I,J)$ may not apply. This may, for example, be due to obstructions between the nodes that may cause the attenuations to be larger than predicted. Also, the transmission properties of the media may be asymmetric resulting in $w(i, j) \neq w(j, i)$. In this paper, we assume the most general case in which edge weights may be asymmetric and may reflect the presence of obstructions in the broadcast path.

Our basic idea starts from the extendable management of short key chains. In essence, we make two levels of chains having distinct time intervals cross-

authenticate each other (Fig. 1a) to provide permanently extendable chains. Our protocol X-TESLA, read either as eks TESLA or cross TESLA, stands for extendable TESLA. As with other TESLA variants, X-TESLA provides broadcast authentication, under the assumption that the base station and sensor nodes are loosely time synchronized with a known maximum synchronization discrepancy.

2. PROBLEM DEFINITION

2.1 64-Bit Key Chain 1

A short 64-bit key chain is desirable for efficiency in resource limited sensor nodes, but care must be taken, even with short time intervals. As we show, if the chain is generated in a straightforward manner, Time-Memory-Data (TMD) tradeoff techniques can be applicable, leading to discovery of future keys.

2.2 Sleep Mode or Network Failure 2

If sensor nodes go into a sleep mode or key disclosure messages are lost frequently, X TESLA may force heavy key computation to be done at once on sensor nodes for chain verification, during which incoming packets get dropped. If Commitment Distribution Messages (CDMs) are missing, multilevel X TESLA makes nodes wait and buffer for the long interval of upper levels, during which incoming packets are dropped due to the buffer limit.

2.3 Idle Sessions 3

Even for idle sessions with no broadcasts, X TESLA forces chain computation for sensor nodes. Key disclosure messages should be broadcast constantly or heavy computation needs to be done later. Multilevel X TESLA needs CDMs to be broadcast for higher levels, with the number of CDMs increasing with the number of levels.

2.4 Extended Lifetime 4

With node malfunctions and premature power exhaustion, there are needs for node additions [1] or rechargeable sensor nodes [8]. Thus, the lifetime of a network may extend beyond that of each node. As noted in [5], [19], lifetime extension was not clearly considered in X TESLA. Multilevel X TESLA should also fix the lifetime.

2.5 DoS Attacks 5

To resist DoS attacks, multilevel X TESLA requires many CDMs to be distributed for longer intervals. Its DoS tolerant version needs sufficiently large buffers on sensor nodes for random selection of received CDMs. The DoS-resistant version requires CDMs to be received stably along with a larger packet and additional hash function.

Let T be a broadcast tree. Following a broadcast using the broadcast tree T , the residual energy, $re(i, T)$, at node i is

$$re(i, T) = ce(i) - \max\{w(i, j) | j \text{ is a child of } i \text{ in } T\} \geq 0$$

The critical energy, $CE(T)$, following the broadcast is defined to be

$$CE(T) = \min\{re(i, T) | 1 \leq i \leq n\}$$

In the maximum critical energy problem (MCEP), we are given a network and a source node s and are to find a broadcast tree T rooted at s such that $CE(T)$ is maximum. This maximum value of $CE(T)$ is called the maximum critical energy and is denoted $MCE(G, s)$. Intuitively, by using a broadcast tree T that maximizes $CE(T)$, we maximize our chances of being able to complete the next broadcast request. Hence, we expect to prolong network lifetime by maximizing $CE(T)$ following each broadcast.

Algorithm for MCE (G, s)

Given a source node s , our strategy to determine $MCE(G, s)$ is to first obtain a sorted list, L , of candidate values for MCE. Next, we perform a binary search on the values in L to determine $MCE(G, s)$.

Determine Candidate List L

For each node i of G , define the set $a(i)$ of residual energy values as below.

$$a(i) = \{ce(i) - w(i, j) | (i, j) \text{ is an edge of } G \text{ and } ce(i) \geq w(i, j)\}$$

Let $l(i)$ denote the set of all possible values for $re(i)$ following the broadcast. We see that

$$l(i) = \begin{cases} a(i) & \text{if } i = s \\ a(i) \cup \{ce(i)\} & \text{otherwise} \end{cases}$$

Consequently, the sorted list of all possible values for $MCE(G, s)$ is given by

$$L = \text{sort}(\cup_{1 \leq i \leq n} l(i))$$

We assume that G is represented using adjacency lists [3]. Since each $l(i)$ may be computed in $O(d_i^{\text{out}})$ time, where d_i^{out} is the out-degree of node i , all $l(i)$ may be computed in $O(n + e) = O(e)$ time. From the $l(i)$ s, L may be computed in $O(e \log e)$ time using a sort method such as merge sort [3]. So, the total time needed to compute L is $O(e \log e)$. Note that $|L| = O(e)$. Let compute $L(G, s)$ denote an algorithm that determines the sorted list L using the strategy just described.

3. X-TESLA: SECURE AND EFFICIENT BROADCAST AUTHENTICATION PROTOCOL

3.1 Overview of X-TESLA

Our basic idea starts from the extendable management of short key chains. In essence, we make two levels of chains having distinct time intervals cross-authenticate each other (Fig. 1a) to provide permanently extendable chains. Our protocol X-TESLA, read either as eks TESLA or cross TESLA, stands for eXtendable TESLA. As with other TESLA

variants, X-TESLA provides broadcast authentication, under the assumption that the base station and sensor nodes are loosely time synchronized with a known maximum Synchronization discrepancy.

- The lower level chain naturally authenticates the next upper level chain, as they are connected in a single chain by construction. Commitment of the next lower level chain repeatedly.

The crossing of Fig. 1a illustrates the followings:

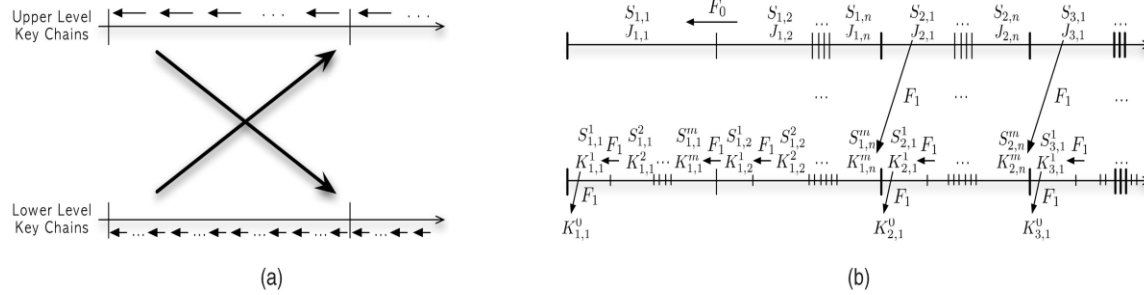


Fig. 1. Basic concept of X-TESLA. (a) Cross authentication. (b) Basic flows.

Multiple distinct keys in the upper level chain authenticate the initial value. The repeated authentication will help in resolving problems from DoS attacks, sleeping nodes, and idle sessions.

4. X-TESLA DETAILS

4.1 Initialization

We assume a base station broadcasts authenticated messages to sensor nodes. A method to choose salt values is fixed at system design phase. The base station generates the first upper level chain by choosing seed key $J_{1,n} \in K$ at random and also generates the first lower level chain together with the second upper level chain by choosing another seed key $J_{2,n} \in K$ randomly. The values $J_{1,0} = F_1(J_{1,1}, S_{1,1})$ and $K_{1,1}^0$ are stored in each sensor node as initial upper and lower level commitments, respectively. Depending on the way salt is chosen, some extra information may also need to be stored. It would be advisable to keep these values secret until just before deployment. Generation of the second lower level chain together with the third upper level key chain should soon follow, so as to be ready for commitment distribution. When the initialized nodes are deployed, they are to be loosely time synchronized with the base station, as assumed in X TESLA.

4.2 Broadcast authentication

During an $I_{u,v}^w$, the base station uses $K_{u,v}^w$ as the MAC key for Types 1, 2, and 3 packets being sent out, and reveals $K_{u,v}^w$ after a wait of time δ from the end of $I_{u,v}^w$, in Type 2 or 3 packets. We shall abuse interval indices, setting

The following is a Type 2 packet for use with “ δ =one time interval.” Here, j denotes

$$I_{u,n+1}^j = I_{u+1,1}^j, I_{u,v}^{m+1} = I_{u,v+1}^m, I_{u,0} = I_{u-1,n}, \text{ and } I_{u,v}^0 = I_{u,v-1}^m.$$

concatenation and signifies the index and data portion.

$$T2P_{u,v}^w = \langle u, v, w \rangle \| \text{data} \| \text{MAC}_{K_{u,v}^w}(\cdot) \| K_{u,v}^{w-2}.$$

Commitment Hopping With TESLA variants, there are at least two situations in which verification of a newly disclosed key places heavy computational load on a sensor node, resulting in many message drops, for the duration of this computation. First, if a sensor node falls into sleep mode or turns off its radio power to save energy, it may not be able to listen to the key disclosure messages during that period. Second, if there are long idle periods with no broadcast, it would be wasteful to disclose keys on schedule and a base station might minimize the key disclosures for those periods. As a result, there could be a large gap between the current commitment and the key to be verified. Type 3 packets can resolve this problem, by providing commitment hopping. Let $I_{u',v'}$ be an interval appearing after $I_{u,v}$. The distance between the two intervals depends on the application needs. We set

$$T3P_{u,v}^w = \langle u, v, w \rangle \| K_{u',v'}^m \oplus J_{u',v'} \| \text{MAC}_{K_{u,v}^w}(\cdot) \| K_{u,v}^{w-2}.$$

The future lower level key $K_{u',v'}^m$ is masked by the future upper level key $J_{u',v'}$ and distributed in $I_{u,v}^w$. A node can authenticate it quickly within a few lower intervals, but Unmask it afterwards only when $J_{u',v'}$ is obtained. After unmasking, it may replace the current lower level commitment, should it be older. In the opposite direction, $K_{u',v'}^m$ can be used to reveal $J_{u',v'}$. If v' is close to n , $K_{u',v'}^m$ can be used as the next upper level commitment.

4.3 Cross authentication

With X-TESLA, keys of the upper level chain can be authenticated by the previous lower level chain since they are connected in a single chain by construction and since the latest commitment key of the previous lower level is available to sensor nodes. Type 3 packets further help in making this available. After any verification, the commitment for the upper level can be updated. For authentication of a new lower level chain, the upper level chain is used. The following is a Type 4 packet. It distributes the commitment of the next lower level chain while disclosing a previous upper level key.

$$T4P_{u,v} = \langle u, v \rangle \| K_{u+1,1}^0 \| MAC_{J_{u,v}}(*) \| J_{u,v-1}$$

4.4 Flexible constructions

We now place more flexibility, in addition to the choice of chain lengths, into the X-TESLA construction. This will resolve even the most extreme situation that could occur with Type 4 packets. Starting from the basic flow of Fig. 3a, we extend the upper level chain over a Number of lower

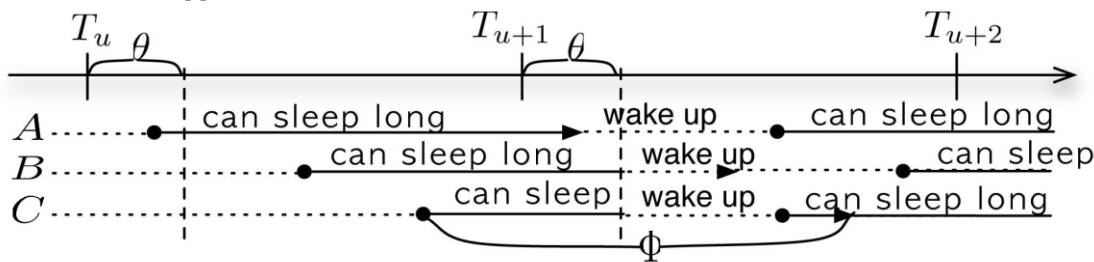


Fig. 4. Sleep mode in X-TESLA.

4.5 Sleep mode management

Energy efficiency is mandatory for sensor networks since tiny nodes are operated on batteries. Various types of sleep modes that stop CPUs or radio functions are commonly used but care must be taken [16], as nodes that have been inactive for a long time may need to do much computation for key verification or lose commitment.

Let T_u denote the starting time of interval I_u , and set $\Phi = T_{u+1} - T_u$ to the length of one upper level chain. As depicted in Fig. 4, a sensor node shall not be allowed to go into a long-term sleep or, at the least, not be allowed to stop radio functions for a long-term period unless it has obtained the next lower level commitment, while short-term sleeps are always allowed. More specifically, we fix some threshold value θ that takes the clock discrepancy of

level chains for better survivability against high communication faults and long idle sessions, as depicted in Fig. 3b. Even a short extension of the upper level chain with only small bits allows many lower level chains to be attached, and these may be generated on the fly.

The extension increases stability of chain verification in both levels. The change also provides longer periods in which to distribute the next chain commitments for both levels through Type 3 and Type 4 packet variants. The reverse flow depicted in Fig. 3c allows reduction of Type 4 packets for environments in which authenticated messages are broadcast very frequently. Since an upper level chain serves as commitments for the next lower level chain.

Type 4 packets distribute $J_{u+1,0} := F_0(J_{u+1,1}, S_{u+1,1})$ instead of $K_{u+1,1}^0$ in this version. But the dependence on Type 4 packets is smaller, because the upper level keys can be recovered stably from Type 3 packets if the authenticated broadcasts of the lower level are very frequent. The hybrid flow of Fig. 3d, offers extreme durability.

nodes into account, and for a node that has verified a Type 4 packet at time T , we allow it to set the maximum sleep length timer Φ to the duration of up to Φ only if $T < T_u + \theta$ (as in node A of Fig. 4), and to the duration of up to $T_{u+1} + \theta - T$ if otherwise (as in nodes B and C of Fig. 4).

5. TWO NEW HEURISTICS FOR BROADCAST TREES

We describe two new greedy heuristics—BIPLA (broadcast incremental power with look ahead) and MEN (maximum energy node)—to construct broadcast trees. The first of these (BIPWLA) is an adaptation of the look ahead heuristic proposed by Guha and Khuller [12] for the connected dominating set problem. This heuristic, which also may be viewed as an adaptation of BIPPN, attempts to construct broadcast trees with smaller energy requirement by doing a limited look ahead. The second

heuristic (MEN) doesn't explicitly attempt to construct broadcast trees with low energy requirement. Rather, it favors the use of high-energy nodes as relays (non-leaf nodes) of the broadcast tree so as to preserve the energy of low-energy nodes. This strategy is expected to increase lifetime.

The BIPLA Heuristic:

Let $ce(i)$ be the current energy at node i of the network before sending a message. In BIPWLA, we begin with a tree T that comprises the source node s together with all neighbors of s that are reachable from s using $ce(s)$ energy. Initially, the source node s is colored black, all other nodes in T are gray and nodes not in T are white. Nodes not in T are added to T in rounds. In a round, one gray node will have its color changed to black and one or more white nodes will be added to T as gray nodes. It will always be the case that a node is gray if it is a leaf of T , it is black iff it is in T but not a leaf, it is white if it is not in T . In each round, we select one of the gray nodes g in T ; color g black; and add to T all white neighbors of g that can be reached

using $ce(g)$ energy. The selection of g is done in the following manner. For each gray node $u \in T$, let n_u be the number of white neighbors of u reachable from u by a broadcast the uses $ce(u)$ energy. Let p_u be the minimum energy needed to reach these n_u nodes by a broadcast from u . Let,

$$A(u) = \{j | w(u, j) \leq ce(u) \text{ and } j \text{ is a white node}\}$$

We see that $n_u = |A(u)|$ and $p_u = \max\{w(u, j) | j \in A(u)\}$. For each $j \in A(u)$, we define the following analogous quantities Node g is selected to be the gray node u of T that maximizes $n_u/p_u + \max\{n_j/p_j | j \in B(u)\}$ required energy. The BIPWLA heuristic is summarized in Figure 5.

Once the broadcast tree is constructed, a sweep is done to restructure the tree so as to reduce. The is a broadcast tree. Finally, a sweep is done to restructure the tree so as to reduce

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Heuristic BIPWLA(G, s) {
    Step 1: // construct a broadcast tree T
    T = {s} ∪ {j | w(s, j) ≤ ce(s)};
    Color s black, and all other nodes of T gray, all nodes not in T white.
    while |T| < n do {
        Let g be the gray node u of T that maximizes n_u/p_u + max{n_j/p_j | j ∈ B(u)}.
        Make g a black node.
        Add the nodes of A(g) to T as children of g.
        Color the nodes of A(g) gray.
    }
    Step 2: Perform a sweep over the nodes, restructuring T to reduce total energy required by broadcast tree.
}
    
```

When T contains all nodes of G (i.e., when T the required energy. The MEN heuristic is summarized in figure 6.

Figure 5: BIPWLA minimum energy broadcast tree heuristic

The MEN Heuristic

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Heuristic MEN(G, s) {
    Step 1: // construct a broadcast tree T
    T = {s};
    while |T| < n do {
        Let Q be as defined in Equation 1.
        Let u ∈ Q be such that ce(u) is maximum.
        T = T ∪ {neighbors j of u not in T for which w(u, j) ≤ ce(u)};
    }
    Step 2: Perform a sweep over the nodes, restructuring T to reduce total energy required by broadcast tree.
}
    
```

Figure 6: MEN minimum energy broadcast tree heuristic

The MEN (maximum energy node) heuristic attempts to use nodes that have more available energy as non-leaf nodes of the broadcast tree thereby preserving the energy of low-energy nodes, which become, From Q, we

6. CONCLUSION

select the node u that has maximum energy $ce(u)$. All neighbors j of u not already in T and which satisfy $w(u, j) \leq ce(u)$ are added to T as children of u . This process of adding nodes to T terminates leaves of the broadcast tree (recall that the leaves of broadcast tree expend no energy in our model). In MEN, we start with $T = \{s\}$. At each step, we determine Q such that

$$Q = \{u | u \text{ is a leaf of } T \text{ and } u \text{ has a neighbor } j, j \notin T, \text{ for which } w(u, j) \leq ce(u)\} \quad (1)$$

significantly by incorporating the critical energy constraint into each minimum-energy broadcast tree heuristic. We have proposed X-TESLA, an efficient scheme which may continue indefinitely and securely, that addresses this and many other issues of the previous schemes. With the advent of more powerful sensor node commodities such as iMote2, the future of public-key technique application to broadcast authentication looks bright, but X-TESLA can efficiently be combined with public-key techniques also.

For example, we could modify X-TESLA to use digital signatures on Type 4 packets, keeping everything else the same.

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Our work shows that although minimum energy broadcast tree heuristics result in low-energy broadcast trees, the use of these broadcast trees doesn't result in good network lifetime. Network lifetime is enhanced

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