RESEARCH ARTICLE OPEN

Hidden Data Procession for Multiple Applications in Wireless Sensor Networks

JanarishSaju C[1], Sharon NishaM[2]
1PG Scholar, Department of CSE, Francis Xavier Engineering College,Tirunelveli, India
2Associate Professor, Department of CSE, Francis Xavier Engineering College,Tirunelveli, India

Abstract—
In wireless sensor networks hidden data procession is the concept of collecting, summarizing and combining sensor node's data in order to reduce the amount of data transmission in the networks. In previous studies we have found that homomorphic encryption algorithm have been applied to hide data during aggregation from sensor nodes. However the principle involved in this algorithm does not satisfy multiple application in sensor environment, and second compromising node attack cannot be prevented and then finally the number of messages aggregated could be detected and whether it may be a duplicate copy, therefore a new scheme "Hidden Data Procession" has been introduced which is an extended form of Boneh et al's homomorphic CRT algorithm such that the security schemes are applied using "Key Distribution" technique, since it has three methodology to satisfy the above mentioned problem. Initially it was designed mainly for multi-application environment and second it prevents compromising node attack and finally a special method of secure counting is applied here, to prevent unauthorized data sensed.

Keywords—Hidden data procession, Chinese redundancy theorem,key distribution techniques and wireless sensor networks.

I. INTRODUCTION

A wireless sensor network is a network consisting of various separated devices called sensors to detect environmental conditions. A wireless sensor network system provides the way of connecting many sensor nodes. It incorporates wireless connectivity of combining sensor nodes for a separated environment (see Figure 1). The wireless technology depends on your application requirements. The required applications include radio transmission, Wi-Fi connectivity, long term Bluetooth devices or satellite transmission etc. The WSN is built of "nodes" – from single to thousands of sensor nodes. Each and every sensor node has several method of construction: a radio transceiver with an internal antenna or connection to an outside antenna. Also there are many typical construction interfacing with the sensors networks.A sensor node might act like a planet surrounding the sun, which means the sun which acts like a group head. In case of sensor environment the each and every sensor node may considered to be cluster head according to the application requirements. The costs of sensor nodes are unpredictable depending on the utilization of sensor nodes.

Figure 1WSN Components, Gateway, and Distributed Nodes

II. RELATED WORKS

In [1] Perrig.A,et.al,(2011) proposes "SIA: Secure Information Aggregation in Sensor Networks" This is the paper which constructs framework for securing the data in sensor environment. Here the sensor nodes which act like the aggregator according to the query evaluated which strictly reduces the communication overhead, the information responded according to the query is in the form of average or median of the corresponding values. This can be achieved by constructing random sampling or interactive proofs. So even if the corresponding sensor nodes are corrupted, the sampling model of collected information provides the result to the user.

And also it enables the sub linear communication between aggregators and the users, and this was the first technology evolved for secure aggregating protocol that can handle malicious attack on sensor nodes.

In [2] Stankovic,et.al,(2010) deals with "Security in Wireless Sensor Networks: Issues and Challenges" which describes a great purposes for various future applications, the inclusion of wireless communication technology in this paper includes several methods of security applications. The intent of this paper is to monitor the related security problems and occurrences in wireless sensor networks. This mechanism detects the security problems and proposes security solving applications for wireless sensor networks. This study also discusses the major view of security for implementing future, fast, and accuracy of security in wireless sensor networks. According to the use of layered codes, group heads of sensor environment does not knowhow the sensor data to perform data procession, which enables sensor nodes to communicate end-to-end secure communicationwith base station to the related sensor nodes.

In [3] David Evans,et.al,(2007) focuses on "Secure Aggregation for Wireless Networks", Here also the same criteria used as mentioned above such that the sensor nodes in proposed environment collects the data or information and distributed to the requested base station. To balance energy, intermediate sensor nodes should collects information from separate sensors nodes. However, this evaluates the risk of compromising any of the sensor nodes and provides false reading. In this paper the mechanism of new protocol was designed to avoid the compromising node attack. Here this protocol is designed with minimum energy or power, minimum cost and inexpensive sensor nodes.

In [4] HasanÇam,et.al,(2007) proposes a secure and energy considerable data aggregation protocol called ESPDA (Energy-Efficient Secure Pattern based Data Aggregation). ESPDA avoids the repeated data transmission from sensor nodes to group head called cluster head. If sensor nodes aggregate the same data repeatedly from sensor nodes, this approach gathers data and collected in the form of pattern code representation to determine the characteristics of data sensed. Cluster-heads collects the data aggregated and securely transmitting to the base station in the form of cipher texts. And this mechanism provides the way of communication by end-end process of data aggregation mechanism.

In [5] Cam.H,et.al,(2008) proposes a secure data aggregation protocol, called SRDA. SRDA requires sensor nodes to send only the difference obtained data instead of all data aggregated by the sensor nodes. Effectiveness of the SRDA is managed by the key distribution technique in case of security purposes. SRDA establishes secure connectivity among sensor nodes. The incremental security requirement for data aggregation evaluates significant result's that show SRDA technique yields preserve data security by minimizing the energy consumption.

III. SYSTEM DESIGN

The problem of aggregating data from sensor nodes directly to the base station requires more energy consumption, which is satisfied by forming the cluster node to collect data from a group of nodes; this principle is already proposed by traditional approaches. Another need for the problem is that it haven't secured while collecting data for multi-application environment, since previous studies show that the security is made over only for single application environment. And finally third problem shows that the base station does not know how many times the sensor has been sensed, since there may be a chance for wrong update from unauthorized access. Therefore these problems need a quick remedy and solutions, which can be resolved by our "Hidden Data Procession" approach.

A.Existing System:

In wireless sensor networks data procession is the scheme of collecting data from several nodes and securely passing them to base station, which reduces the large amount of transmission, here the traditional approach of "Homomorphic Encryption" algorithm have been applied, this method supports for an effective single application environment, but there is a risk for multi-application environment, since the enciphering of data for several application cannot be aggregated together, because the decrypted aggregated result will be incorrect. And the existing methodology does not counts the number of aggregated messages, which results unauthorized update or editing on the cluster head and here there is no proved security for the compromised node attack of the same.

B.Proposed System:

The proposed scheme is the "Hidden Data Procession" method, which introduces the new extended form of "Boneh et al's Homomorphic Encryption Algorithm". This is a key distribution technique and is formally related with (CRT-Chinese Reminder Theorem) algorithm, which encrypts the data from multi-application environment, such that the cipher texts from different application can be encapsulated into only one cipher texts, whereas the corresponding base station can extracts the application related plaintext via the corresponding secret keys allotted. This scheme is specially designed to prove three contributions that do not satisfy previous studies of data procession technique

in which the first contribution is that it was designed especially for multi-application environment, and second it mitigates compromising attack in cluster head, and finally it degrades the damage from unauthorized updating or editing sensor readings.

III. BGN Scheme

In 2006, Boneh et al. [3] proposed a public-key PH scheme, which integrates the Paillier [9] with the Okamoto- Uchiyama encryption schemes [2]. We call it BGN forsimplicity. BGN provides the way of ensuring addition, multiplication and modulo homomorphism. Here the property of multiplication is based on pairing with bilinear operations. [3], is more expensive and complex [1], Here we propose additive, multiplication, and modulo operation. In this paper, it shows the BGN scheme of operation for data collection. Here we modify BGN scheme to satisfy multiple applications in sensor nodes. The explanation about BGN is showed in Fig 2.BGN is evaluated in the form of elliptic curvepoints by representing cyclic points. However the point representation form an algebraic group,and similarly I denotes the identity points. [2], Here (P) denotes the notation of order of P.Showing ord(P) ¼ q, it shows that it is the minimum integer of q represents q _ P ¼1. In the key generation function the order E is equal to the total number of points in E.The explained concept of E is mentioned above. The function of ENC is based on points G and H which is the scalar multiplications over that. The cipher text is designed in form of many parts. Where the scalar representation of points is considered to be point over G and Scalar of randomness is considered to be point over H. The homomorphic properties which proves the additive property; the scalar value of point p is added at the end gives the sum of total aggregated messages. Consequently,the final output gives the representation M _ G þ R_H,Here M and R is the number of messages and effectiveness of randomness consequently. The decryption function DECRYPT gives the output M which is the number of messages aggregated. Here both the points G and H are different. By multiplying the results with private key the randomness of the point H is removed represents ord(H). Here the cipher texts contains only the product of H representing the function as ord(H) _M _ G . In order to apply the value of M we should use discrete sample of algorithms. Here its efficiency is obtained by Pollard's method.Now, we make a glance at the algorithm, when the sensor nodes S1 have sensed the reading M1, S1 encrypts M1 and gives the solution as C1, which is the cipher text.Then S1 sends the cipher text C1 to AGG which is an aggregator. When AGG receives all cipher text C1….Cn, which is given in the expression AGG(_ _ _ AGG(AGG(C1; C2Þ; C3Þ _ _ _C_). Then it sends to the next generator.

KEYGEN(τ): generate a public-private key pair
1. Based on security parameter τ, it computes a triple elements, $(q_1,\ q_2,\ E)$
   where E is a set of elliptic curve points which form a cyclic group.
   The order of E, ord(E), is n where n equals to the product of q_1 and q_2; q_1 and q_2 are large primes.
2. Randomly select two generators (i.e., base points) $\mathcal{G}$, $\mathcal{U}$, where ord($\mathcal{G}$) = ord($\mathcal{U}$) = n.
3. Compute point $\mathcal{H} = q_2 * \mathcal{U}$ such that ord($\mathcal{H}$) = q_1.
4. Select parameter T as the maximum plaintext boundary and $T < q_2$.
5. Output the public key: $PK = (n, E, \mathcal{G}, \mathcal{H}, T)$.
6. Output the private key: $SK = q_1$.

ENC($PK,\ M$): Message encryption on M by public key PK.
1. Check if message $M \in \{0, \cdots, T\}$.
2. Randomly select $R \in \{0, \cdots, n-1\}$.
3. Generate the ciphertext C as: $C = M * \mathcal{G} + R * \mathcal{H}$, where $\mathcal{G}, \mathcal{H} \in PK$.
4. Output C.

AGG($C_1,\ C_2$): Aggregation on two ciphertexts C_1, C_2.
where $C_1 = M_1 * \mathcal{G} + R_1 * \mathcal{H}$ and $C_2 = M_2 * \mathcal{G} + R_2 * \mathcal{H}$.
1. Randomly select $R' \in \{0, \cdots, n-1\}$.
2. Compute the aggregated ciphertext of $(m_1 + m_2)$, C' as:
   $C' = C_1 + C_2 + R' * \mathcal{H} = (M_1 + M_2) * \mathcal{G} + (R_1 + R_2 + R') * \mathcal{H}$.
3. Output C'.

DEC($SK,\ C$): Message decryption on C by private key SK
1. Compute $\log_{\tilde{\mathcal{G}}}(q_1 * C) = \log_{\tilde{\mathcal{G}}}(q_1 * (M * \mathcal{G} + R * \mathcal{H})) = log_{\tilde{\mathcal{G}}}(M * q_1 * \mathcal{G}) = M$ where $\tilde{\mathcal{G}} = q_1 * \mathcal{G}$.
2. Output M.

Figure 2BGN scheme.

IV. HIDDEN DATA PROCESSION

BGN is proposed by the order of implementing two point constructions G and H which was described as earlier. By the representation of two points of order one of the orders can be removed by multiplying with response to aggregated solutions, and finally the scalar representation of another point is detected. By using the same logic hidden data

procession is applied for multiple representations. We can access one scalar operation of certain point by removing the effects of remaining points, this is done by multiplying the collection of encrypted cipher textalong with the remaining points product). The security ofhidden data procession concept and BGN are based on subgroup decision problem. Here we represent hidden data procession(k ¼ 2) to derive how we use for multiple applications.

A. Hidden Data Procession (k = 2) Construction

In this representation it shows that all the sensor nodes are grouped together separately. It contains four steps: encryption, decryption, aggregation and key distribution techniques. And similarly (k=2) concept is applied here by using P,Q,H schemes whose order of representation is given by q1,q2,q3. The scalars of the first two points carry theaggregated messages in GA and GB, respectively, and thescalar of the third point carries randomness for security. Asshown in the DEC functions, by multiplying the aggregatedcipher text with q2q3 (i.e., the SK in GA), the scalar of thepoint P carrying the aggregated message in GA can beobtained. Similarly, by multiplying the aggregated cipher textwith q1q3 (i.e., the SK in GB), the scalar of the point Qcarrying the aggregated message in GB can be obtained. Inthis way, the encryptions of messages of two groups can be represented in the form of single cipher text, and the aggregated information of particular group or cluster can be encrypted bySK secret key it should be confidentially kept secret similarly the corresponding secret key should be known only by the base station. And the public key shouldbe shared by the dispersed sensor node. And another major operation is the decryption procedure every encrypted result could be decrypted individually.

B. Generalization of Hidden Data Procession

Hidden data procession (k ¼ 2) is generalised by expanding K<2 representation. This generates different key pairs for each group of sensor nodes. To prove the efficiency of security the order of M could be expanded as large enough. Therefore when the value of k becomes more the efficiency of cipher texts also be more. For representing multiple application representation, the sensor nodes belonging to the applications are assigned with same public key. Under this concept the information from different sensor nodes are collected and encrypted in the form of single encrypted text and it can be transmitted to the base station. The base station decrypts the result individually from the single cipher text.

C. Key Distribution

There aretwo methods represented here one among them is key distribution. If we know the locations of deployed SNs, we can preload necessary keys and functions into SNs and AGs so that they can work correctly after being spread out over a geographical region.Key postdistribution. Before SNs are deployed to their geographical region, they are capable of nothing abouthidden data procession keys. These SNs only load the key shared with the BS prior to their deployment, such as the individualkey in LEAP [3] and the master secret key in SPINS [4]. Once these SNs are deployed, they can run the LEACHprotocol [2] to elect the AGs and construct clusters. After that, the BS sends the corresponding hidden data procession keys,encrypted by the preshared key, to SNs and AGs.

V SECURITY ANALYSIS AND COMPARISON

In this section, we propose the security concepts applied in the hidden data procession. Here we comparehidden data procession security problem schemes.

A1. Ciphertext knownattack. Which is the basic attack happened at the sensed node

A2. Known plaintext attacks. Only CDA based onDomingo-Ferrer scheme [17] might suffer from this attackdue to improper security parameters indicated by Wagner'scryptanalysis [35]. However, the cost of properparameters may render CDA infeasible to WSNs. ForCastelluccia et al.'s scheme, although the previous encryptionkeys can be deduced by the pairs, no research showsthat these keys help the deduction of the present orsubsequent encryption key.

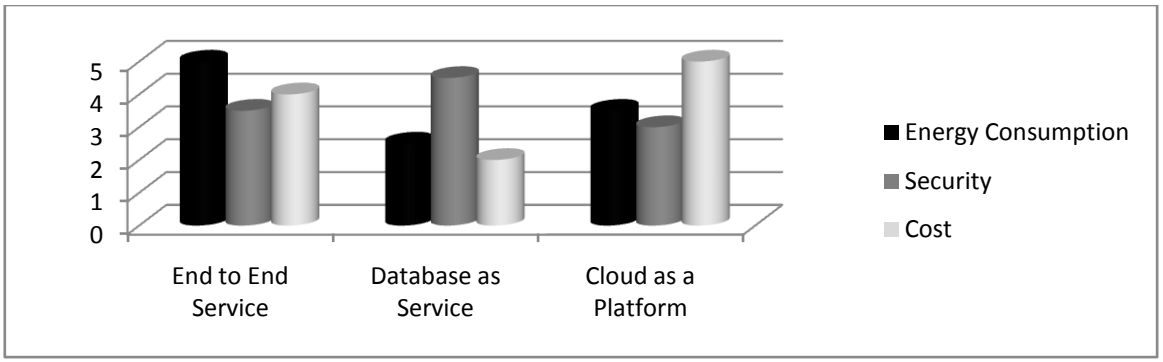
A3. Chosen plaintext attacks. If the scheme suffers fromknown plaintext attacks, then it also suffers from chosen
plaintext attacks. Hence, CDA also suffer from this attack.Other schemes can defend against this attack because theyare probabilistic encryption algorithms. It is hard to decrypta ciphertext by finding a match from known samples.

A4. Chosen ciphertext attacks. Unfortunately, all schemessuffer from this attack due to the homomorphic property.Assume that an adversary tries to decrypt the challengedcipher text C ¼ E (M), where E (-) is a PH's encryptionfunction. The adversary can obtain the ciphertext C00 byadding C with a cipher text C0 ¼ E (M0), whereM0 is known.After that, she can decrypt C00 to its plaintext M00 byquerying the decryption oracle. Consequently, she canobtain M by M ¼ M00 _M0. Fortunately, it is difficult tolaunch this attack in WSNs because the adversary musthave the ability to decrypt some chosen ciphertexts.

B1. Unauthorized aggregation. Since the aggregation ofCDA requires only modular addition, an adversary may
Aggregate ciphertexts without additional information. UnlikeCDA, encryption keys of SNs in Castelluccia et al.'sscheme are generated dynamically for one-time use.Unauthorized aggregation probably results in an unexpectedplaintext because the keys involved in theseciphertexts mismatch with those currently held by the BSwith high probability. Since unexpected plaintexts can beobserved by the BS, the impact of unauthorized aggregationis mitigated. For asymmetric schemes, EC-OU, Tiny-PEDS, BGN, and CDA are based on ECC. To aggregateciphertexts, one has to know curve information. If thepublic key is preinstalled or delivered in a secure way, aggregation cannot be executed by an adversarywithout compromising SNs or AGs.
B2. Malleability. Castelluccia et al.'s scheme suffers fromthis attack because of modular addition-based construction.For example, adding the value of plaintext is trivial by addinga desired numeric value to the corresponding ciphertextdirectly. Other scheme based on modular multiplication(e.g., CDA) or those based on ECC can defend against thisattack.
C1. B1/B2 under compromised AG. For CDA andCastelluccia et al.'s scheme, compromising an AG willdisclose the modulus; for ECC-based schemes, this willdisclose the curve information. Except hidden data procession scheme, revealingcurve information makes unauthorized aggregation in other scheme easier. On theother hand, no malleability is still supported by all ECCbasedschemes because point information stored in SNare not revealed.
C2. Unauthorized decryption under compromised SN. InCDA, when compromising an SN, an adversary candecrypt the aggregated ciphertexts because CDA is asymmetric scheme. Although Castelluccia et al.'s schemeis also symmetric, it suffers from minor impact because eachnode is assigned a distinct key. On the contrary, EC-OU,TinyPEDS, BGN, and hidden data procession do not suffer from thisattack because they are asymmetric schemes.
C3. Unauthorized encryption under compromised SN. This isthe strongest attack against which no schemes can defend.An adversary encrypts arbitrary values with the compromisedsecrets and alters the aggregated cipher text by theforged values. After aggregation, the polluted messagesaggregated into the result would be difficult to remove ordetect. Castelluccia et al.'s scheme can mitigate the impactbecause the adversary cannot forge ciphertexts of uncompromisedSNs. Similarly, hidden data procession ($k > 1$) prohibits adversariesto forge cipher texts of SNs in uncompromisedgroups. Supporting more groups (i.e., bigger k) makeshidden data procession more secure even it brings additional cost; the sizeof ciphertexts increases linearly.

VI PERFORMANCE ANALYSIS

To perform the complex and computation cost. TinyPEDS, EC-OU, GN, andhidden data procession are represented based on elliptical curve cryptographic representation. Here the process of encryption decryption and aggregation are based on two methods they are, addition by a point and scalar multiplication representation of point. In ellipticcurve cryptographic arithmetic algorithm there are two basic operations are performed they are point doublingand adding. The representation of point adding shows the representation P bQ. Here Pand Q are curve points. And 2P is computed by point doubling concept.And similarly the representation r _ Q is computed by scalar multiplication representation. Since r is scalar. These two operations reproduce the half-and-add algorithm[6]. More specifically, computing r _ Q requiresaround jrj doubling and jrj2 additions, amounting to about3jrj2 point additions [11].We have shown the cost relation between point additionand scalar multiplication. Next, we show how to estimatethe cost of scalar multiplication on different finite fields. Ingeneral, the cost depends on the size of the scalar and thesize of underlying finite field. If the size of scalar doubles,the cost doubles too (i.e., linearly inclining). Moreover, if thesize of the finite field doubles, the computation cost isalmost four times the original (i.e., increasing by a power of2). Based on these two rules, the cost of scalar multiplicationon a 1,024-bit field is estimated to be 247.84 (i.e., 1024163 p3)times greater than that on a 163-bit field, where the scalar ischosen from the underlying field.Following the same analysis model in [11], we canestimate computation costs among these schemes. Let thebase unit be the point addition on 163-bit field. For encryptions, TinyPEDS is the most efficient onebecause their curves are chosen from smaller fields. TinyPEDS can be built on smaller fields because itssecurity is based on the hardness of elliptic curve discretelogarithm problem (ECDLP). In contrast to TinyPEDS, thesecurity of EC-OU, BGN, and hidden data procession are based on thehardness of integer factorization problem (IFP). Theircurves have to be chosen from larger fields, resulting inhigher encryption costs.



Performance gain of all the techniques are compared along with the graphical representation, for which it can be compared with three representations of categories they are end to end technology, database as a service and showing cloud as a platform. For each application there could be advantages and drawbacks. See (figure 3) in the above diagram.

A. Performance Gain of Hidden Data Procession

In the above process the computation cost is considerably high. And the data procession is high. This shows that sensors nodes to perform encryption and decryption are complex. To prove the efficiency evaluates the performance gain. Initially we should classify the sensor nodes based on their tasks, and be separated to specific cluster head according to the requirements. Leaf nodes from the tree gather information from the sensor deployed and finally sends the information back to the base station. Aggregated nodes are the sensor nodes which have the collection of information these information can be forwarded to the base station. During this process the energy consumption is measured such that the aggregated results could be minimised by reducing it to single information which is already described above. The data forwarding scheme (DFS) is enhanced to every aggregated node to forward the data to the neighbourhood node. For every data transmission a hop by hop process is enhanced and is secured by applying security mechanism which may be AES and the parent node which stores the encrypted data and finally the base station collects the information in the form of single cipher text. This reduces the amount of data transmission and complexity. Thus proves effectiveness of performance measures.

VII CONCLUSION

Multi-application environment," Hidden Data Procession" is the first Data aggregation scheme. Through "Hidden Data Procession", the encrypted cipher texts from different applications can be collected and combined in the form of single encrypted text. For a single-application environment, it is still more secure than other data aggregation schemes.Whereas it was the first scheme proposed to satisfy multiple information gathered. Whenever compromising attacks occur in WSNs, it provides the way of securing by counting the expected aggregated results. All of this function satisfies through the BGN scheme proposed. Thus it provides database as service in the form of aggregating queries.

In future we may propose PH scheme, which may use cloud as a platform for separating queries rather than database as a service and can be evaluated as much as possible for efficiency.

REFERENCES

[1.] Perrig A., Przydatek B. and Song D.,(2011), 'SIA: Secure Information Aggregation in Sensor Networks,' Proc. First International Conference on Embedded Networked Sensor Systems, pp. 255-265.

[2.] Stankovic and Wagner D., (2009), 'Security in Wireless Sensor Networks,'Comm. ACM, Vol. 47, No. 6, pp. 53-57.

[3.] Evans D and Hu L.,(2007) 'Secure Aggregation for Wireless Networks,' Proc. Symp. Applications and the Internet Workshops, pp. 384-391.

[4.] Hasana Cam, Muthuavinashiappan D., and Sanli.H.O.,(2007), 'Energy-Efficient Secure Pattern Based Data Aggregation for Wireless Sensor Networks,' Computer Comm., Vol. 29, No. 4, pp. 446-455.

[5.] Cam H., Ozdemir S. and Sanli H., (2008), 'SRDA: Secure Reference-based Data Aggregation Protocol for Wireless Sensor Networks,' Proceedings. IEEE 60th Vehicular Technology Conference (VTC '04-Fall), Vol. 7.

[6.] Acharya M., Girao J. and Westhoff D.,(2006), 'Concealed Data Aggregation for Reverse Multicast Traffic in Sensor Networks: Encryption, Key Distribution, and Routing Adaptation,' IEEE

Transaction on Mobile Computing, Vol. 5, No. 10, pp. 1417-1431.

[7.] Girao J., Mykletun E. and Westhoff D.,(2006), 'Public Key Based Crypto schemes for Data Concealment in Wireless Sensor Networks,' Proceedings. IEEE International Conference Communication. (ICC '06), Vol. 5.

[8.] Li Q. and Cao G., (2012), 'Mitigating Aggregated Data in Networks', IEEE Trans. Information Forensics and Security, Vol. 7, No. 2, pp. 45-56.

[9.] Grid.S.J.T.U., Computing Center (2012), 'Shanghai Taxi Trace Data', http://wirelesslab.sjtu.edu.cn ,Vol. 19, No. 8, pp. 32-43.

[10.] Chen D. and Varshney P. (2009), 'A Survey of Void Handling Techniques for Geographic Routing in Wireless Networks', IEEE Communication Surveys and Tutorials, Vol. 9, No. 1, pp. 50-67.

[11.] Boneh D., Rubin.K. and Silverberg A., (2011), 'Finding Composite Order Ordinary Elliptic Curves Using the Cocks-Pinch Method,' Number Theory, Vol. 131, pp. 832-841.

[12.] Bhattacharyas., Luc, Roman G. and Saifullah A., (2010), 'Multi-Application Deployment in Shared Sensor Networks Based on Quality of Monitoring,' Proceedings IEEE 16th Real-Time and Embedded Technology and Applications Symp., pp. 259-268.

[13.] Iyer B., Li C.., and Mehrotra S., (2002), 'Executing Sql over Encrypted Data in the Database-Service-Provider Model,' Proc. ACMSIGMOD International Conference Management of Data, pp. 216-227.

[14.] Hacigu¨mu.H, (2004), 'Efficient Execution of Aggregation Queries over Encrypted Relational Databases,' Proceedings Ninth International Conference .Database Systems for Advanced Applications (DASFAA '04), Vol. 9, pp. 125.

[15.] Liu A. and Ning P.,(2008), 'TinyECC: A Configurable Library for Elliptic Curve Cryptography in Wireless Sensor Networks,' Proceedings International Conference Information Processing in Sensor Networks (IPSN '08), pp. 245-256.