Evaluation on Security System of Internet of Things Based on Fuzzy-AHP Method

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1. INTRODUCTION

- IoT is a network which is through the sensing equipment such as RFID, infrared sensors, GPS, Laser Scanner to connect everything to the Internet to exchange information and communication according to agreed protocols, in order to achieve the goal of intelligent identify, location, tracking, monitoring and management.

1. INTRODUCTION

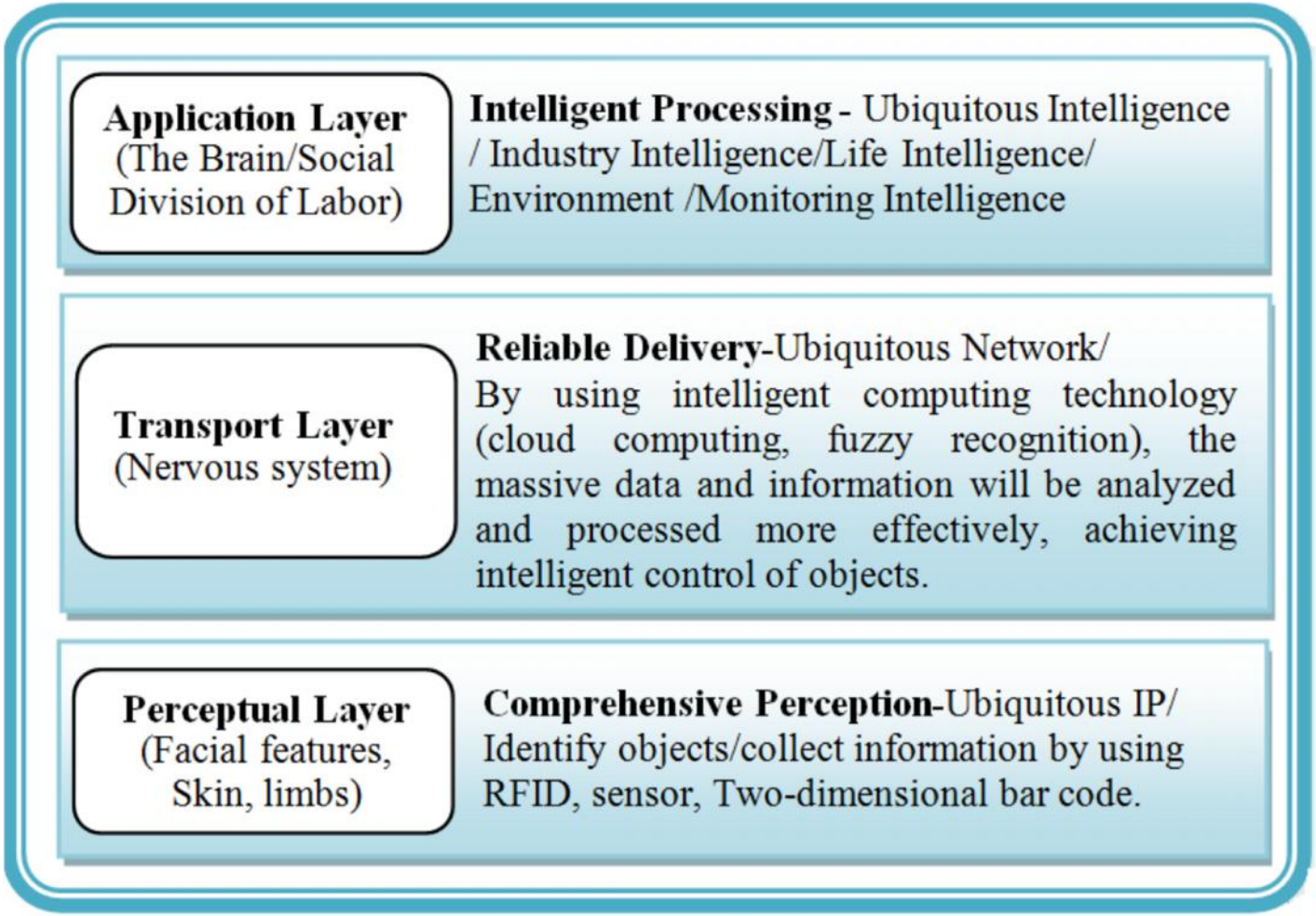

Figure 1. Three Layers of IoT Architecture

2. SECURITY ISSUES OF IOT AND ESTABLISHMENT OF ITS EVALUATION INDEX SYSTEM

2.1 Security Issues of IoT:

The unique threats and attacks to IoT combined with traditional network threats result in three layers facing many challenges actually or theoretically.

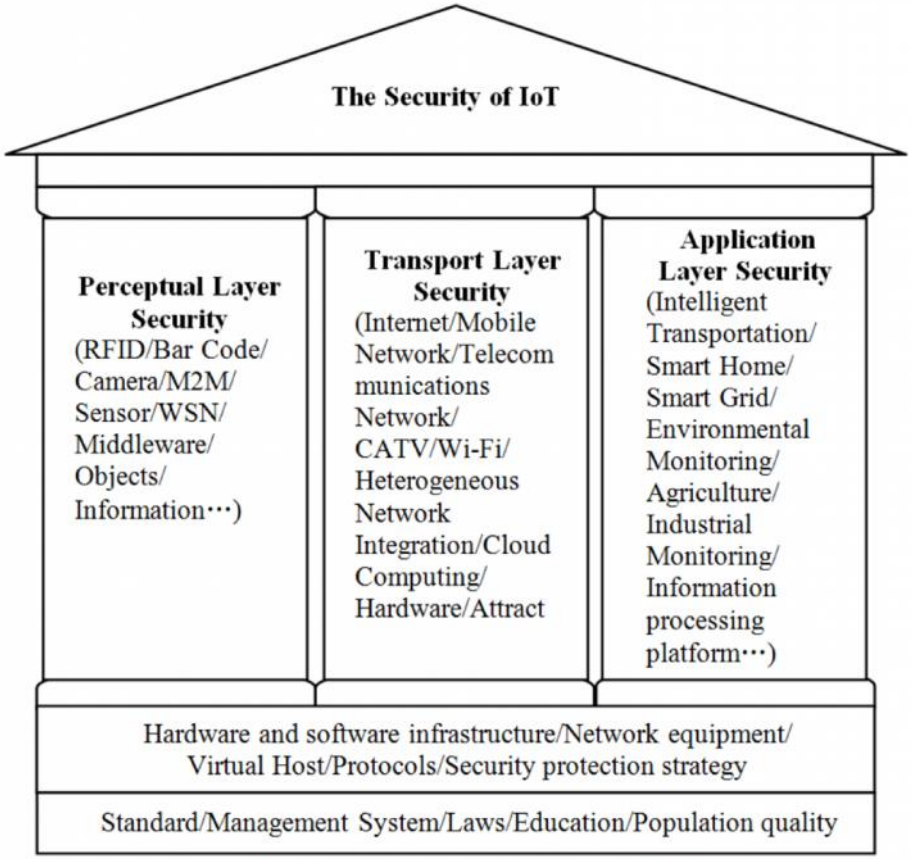

Figure 2. Security-related issues of IoT

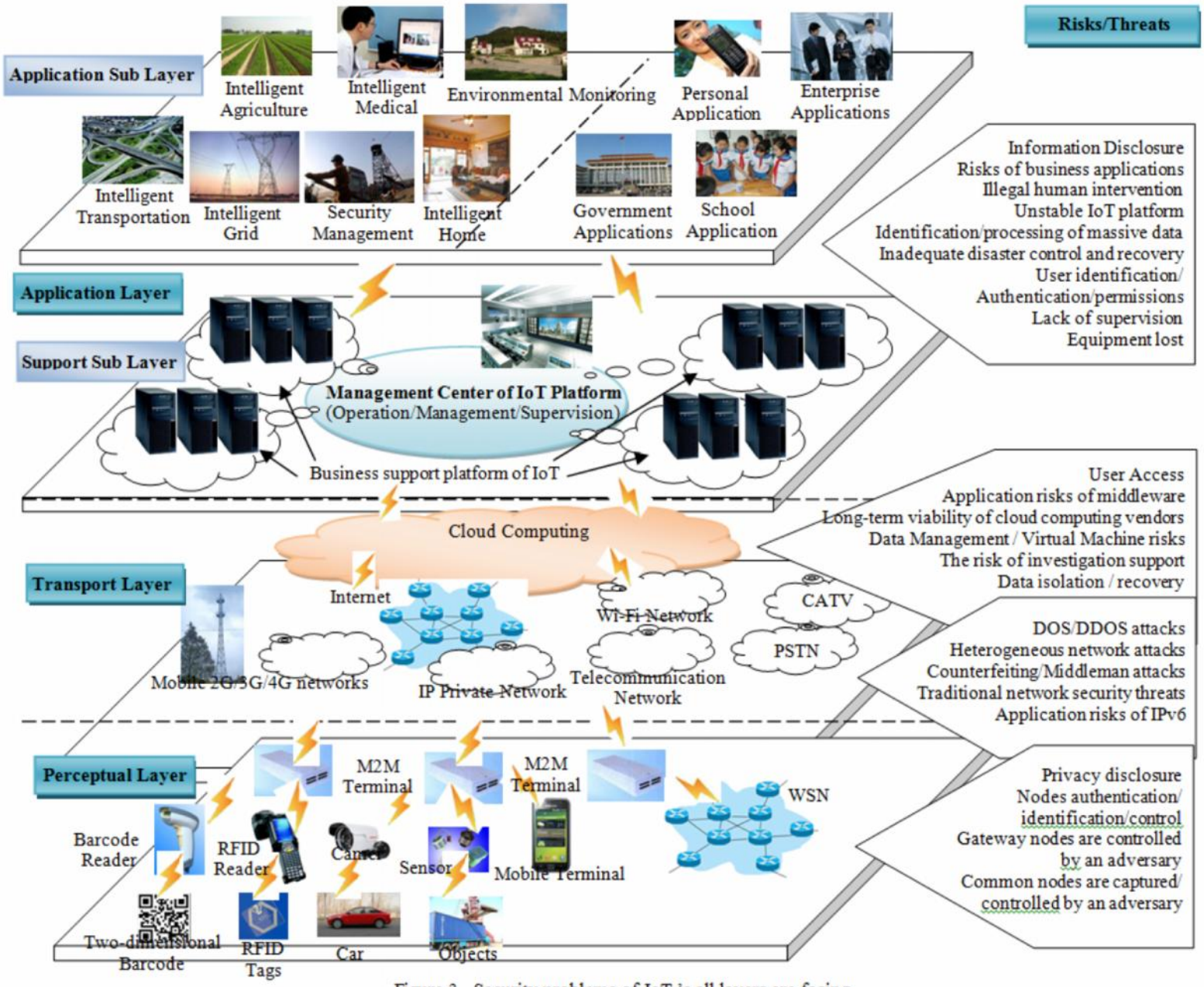

Figure 3. Security problems of IoT 's all layers are facing

- *The Security Challenge of Perceptual Layer*

1. The Security of Wireless Sensor Network (WSN) Nodes

2. Nodes Authentication

3. Information Privacy of Objects

- *The Security Challenge of Transport Layer*

The main threats are: DOS/DDOS attacks; Counterfeiting/Middleman attacks; Heterogeneous network attacks; Application risks of IPv6; Conflicts of WLAN application; Traditional network security threats, etc.

- *The Security Challenge of Application Layer*

Challenges to application sub-layer security are: access; user authentication; information privacy; property protection and payment; how to destroy and track data flow; the stability of IoT platform; platform supervision, etc.

- *The Security Challenge of Cloud Computing*

Cloud computing is the main computing mode of IoT. In its narrow sense, cloud computing refers to the delivery of IT infrastructure and usage through the network to get the necessary resources in an on-demand and scalable way; in its broader sense, cloud computing also refers to service delivery and usage through the network in an on-demand and scalable way.

- 2.2 Evaluation Index System of IoT Security

According to the principles of indicators establishment and the security challenges that all IoT layers are facing, we develop the indicators as shown in Table 1. Target level is the safety of IoT, and perception layer, transport layer, application layer' security are the first-level indexes. In view of the importance of cloud computing in IoT, we specifically consider cloud computing as the first-level index. A few second-level indicators are below every first-level index. And these indicators are used to evaluate the safety of the four IoT platforms (D1-D4).

Target Level	The First-Level Indexes	The Second-Level Indexes	Solution Level (Platforms)
Iot Security (A)	Perceptual Layer Security (B1)	Privacy Security of Objects(C1) Intelligent nodes security(C2) Nodes Information Certification/Control Capability(C3) Anti-attack Capability of WSN(C4)	D1
	Transport Layer Security (B2)	Physical/Environment Security(C5) Network/Communications Security(C6) Software/Data security(C7) Application Risks of IPv6(C8) Heterogeneous Network Recognition/Integration Intensity(C9)	D2
	Application Layer Security (B3)	Role/Identification Efficiency(C10) Business Security(C11) Support Platform Security(C12) Normal Working Hours of Hardware and Software(C13) Disaster Control/Recovery Capability(C14)	D3
	Cloud Computing Security (B4)	User access control Capability(C15) Information Application Security(C16) Data isolation/Recovery Efficiency(C17) Cloud Computing Platform Security(C18) Long-term Survival Time of Suppliers(C19) Cloud Computing Supervision Capability(C20)	D4

3. FUZZY-AHP METHOD EVALUATION MODEL

- Fuzzy comparison scale selection of FAHP method

TABLE 2 0.1-0.9 FUZZY COMPLEMENTARY SCALE

Scale	Meaning	Remarks
0.1	Element x_i is absolutely less important than element x_j	0.2/0.4/0.6/0.8 are medians of adjacent judgment; If the scale of importance elements x_i compared to x_j is r_{ij} , then the scale of importance elements x_j compared to x_i is $r_{ji}=1-r_{ij}$
0.3	Element x_i is obviously less important than element x_j	
0.5	Elements x_i and x_j is equally important	
0.7	Element x_i is obviously more important than element x_j	
0.9	Element x_i is absolutely more important than element x_j	

- ***2 Evaluation Steps of FAHP Method***

FAHP method changes the construction judgment matrix in AHP into construction fuzzy consistent matrix. So satisfied results can be received based on fuzzy consistent matrix, which is used to evaluate the programs with fuzziness.

- Construct Fuzzy Judgment Matrix

If the fuzzy judgment matrixes $R=(r_{ij})_{n\times n}$ meet:

$$r_{ij}+r_{ji}=1, i, j \in I \quad (1)$$

Then the fuzzy matrix R can be called fuzzy complementary matrix.

If the fuzzy judgment matrixes $R=(r_{ij})_{n\times n}$ meet:

$$r_{ij}=r_{ik}-r_{jk}+0.5, \quad \forall i, j, k \in I \quad (2)$$

Then the fuzzy matrix R can be called additive consistency fuzzy complementary judgment matrix or a matrix with additive consistency.

- *Construct Fuzzy Consistent Matrix*

$$\forall\, i, j, k \qquad r_{ij}=r_{ik}-r_{jk}+0.5, \quad \forall\, i, j, k \in I \tag{3}$$

Then the fuzzy matrix R can be called fuzzy consistent matrix.

Sum $_n$ fuzzy comparison matrix R by rows, recorded as $r = \sum_{k=1} r_{ik}$, $i \in I$, then transform as follows:

$$r_{ij} = \frac{r_i - r_j}{2n} + 0.5 \tag{4}$$

- Test of Fuzzy Consistent Matrixes

1. Determine a safe element to judge compared to the importance of other elements. Without loss of generality, assuming that decision makers has a good chance to judge $r_{11},r_{12},\ldots,r_{1n}$.

2. The first row elements of R minus the corresponding elements of the second row. If the income n differences are constants, there is no need to adjust the elements in the second line; otherwise, the elements of the second row should be adjusted. Until the corresponding element differences between the first line and the second line are constants.

3. Repeat the above steps, until the corresponding element differences between the first line and the first n line are constants.

- Calculate the Weight of Each Index and Sort

Relative to the overall goal A, the weight vector of the first-level index

B=(b_1,b_2,…,b_k) is:

$W^{(1)}=(w_1,w_2,\ldots,w_k)^T$ (8)

Relative to the first-level index B, the weight vector of the second-level

index C= (c_1, c_2,…,c_n) is:

$W_l^{(2)}=(w_{1l},w_{2l},\ldots,w_{nl})^T, l=1,2,\ldots,k$ (9)

Relative to the goal level A, we can get the weight vector of the second-level index C by the composition of $W^{(1)}$and $W_l^{(2)}$(l=1,2,…,k). The weight order is:

$$V_j^{(2)} = \sum_{i=1}^{k} w_i^{(1)} w_{jl}^{(2)} \quad , \quad \mathrm{j} = 1,2,\ldots,n; l = 1,2,\ldots,\mathrm{k} \qquad (10)$$

- Establish Fuzzy Comment Sets and Evaluate Each Program Comparatively

Supposing there are m programs, evaluate each program according to the weights of indicators. First, establish fuzzy comment sets, and then invite experts to score on each program in a fuzzy way. p_{jm}(j=1,2,…,n；m=1,2,…,M)is the score that experts score on the program m’s first j indicators. Finally, to eliminate the impact of different dimension, we should to do the dimensionless for the score of each index.

4. A Case Study

Experts judged in a fuzzy way according to the security indicators of IoT, using complementary compared scale of 0.1-0.9. They are fuzzy comparison judgment matrixes of B1～B4 to A and C1～C4 to B1 respectively. The fuzzy comparison judgment matrixes of C5～C9 to B2, C10～C14 to B3 and C15～C20 to B4 were omitted.

TABLE 4. THE FUZZY COMPARISON JUDGMENT MATRIXES OF C1～C4 TO B1

Index B1	C1	C2	C3	C4	$r_i = \sum_{j=1}^{n} r_{ij}$, i=1,…n
C1	0.5	0.7	0.8	0.6	2.6
C2	0.3	0.5	0.6	0.4	1.8
C3	0.2	0.4	0.5	0.2	1.3
C4	0.4	0.6	0.8	0.5	2.3

TABLE 5. THE FUZZY COMPARISON JUDGMENT MATRIXES RESULTS OF C5～C9 TO B2, C10～C14 TO B3, C15～C20 TO B4

	i=1	i=2	i=3	i=4	i=5	i=6
C5～C9 to B2	2.5	3	3.5	1.5	2	—
C10～C14 to B3	2.6	3.4	3	1.4	2.1	—
C15～C20 to B4	3.3	4.2	2.8	3.7	2.3	1.7

- ***Convert into Fuzzy Consistent Matrixes***

Based on fuzzy complementary judgment matrixes, we can construct fuzzy consistent matrix from equation (4). The last column of each fuzzy complementary judgment matrixes is the sum of fuzzy indexes of every line. The constructed fuzzy consistent matrixes are shown in table 6 and table 7. The fuzzy consistent matrixes of C5～C9 to B2, C10～C14 to B3 and C15～C20 to B4 were omitted. The final results are shown in table 8.

TABLE 6. THE FUZZY CONSISTENT MATRIXES OF B1～B4 TO A

Index A	B1	B2	B3	B4	$w_i = \frac{1}{n} - \frac{1}{2a} + \frac{1}{na}\sum_{j=1}^{n} r_{ij}$
B1	0.5	0.6375	0.575	0.5375	0.35
B2	0.3625	0.5	0.4375	0.4	0.15
B3	0.425	0.5625	0.5	0.4625	0.2333
B4	0.4625	0.6	0. 5375	0.5	0.2833

TABLE 7. THE FUZZY CONSISTENT MATRIXES OF C1～C4 TO B1

Index B1	C1	*C2*	C3	C4	$w_i = \frac{1}{n} - \frac{1}{2a} + \frac{1}{na}\sum_{j=1}^{n} r_{ij}$
C1	0.5	0.6	0.6625	0.5375	0.35
C2	0.4	0.5	0.5625	0.4375	0.2167
C3	0.3375	0.4375	0.5	0.375	0.1333
C4	0.4625	0. 5625	0.625	0.5	0.3

TABLE 8. THE FUZZY CONSISTENT MATRIXES RESULTS OF C5～C9 TO B2, C10～C14 TO B3, C15～C20 TO B4

$w_i = \frac{1}{n} - \frac{1}{2a} + \frac{1}{na}\sum_{j=1}^{n} r_{ij}$	i=1	i=2	i=3	i=4	i=5	i=6
C5～C9 to B2	0.2	0.25	0.3	0.1	0.15	—
C10～C14 to B3	0.21	0.29	0.25	0.09	0.16	—
C15～C20 to B4	0.1867	0.2467	0.1533	0.1533	0.12	0.18

- ***Test the fuzzy consistent matrixes***

Because the consistency degree of judgment matrixes can reflect the quality level of judgment matrixes, and has a direct impact on the objectivity and accuracy of the weight vector, we should test the consistence of fuzzy complementary judgment matrixes.

Calculate the Single Ranking Weight and the Total Weight Order

Evaluate the Security Conditions of The Four IoT Platform

TABLE 10 ASSIGNMENT VALUE OF DIFFERENT LEVELS

Grading	Very Good	Good	General	Not very well	Bad
Values Range	90～100	80～90	70～80	60～70	< 60

Result Analysis

In the evaluation results of the four IoT platforms, we can easily conclude the ranking result is D2>D3>D1>D4 and the final scores are: 0.8568, 0.8444, 0.8253 and 0.7973, which indicate that the second platform is better than others. It should be the benchmark for other platforms to learn and it will be the important references to other platforms or even the whole IoT industry.

5. CONCLUSION

- Through the indexes analysis, we conclude that the security issues should focus on perceptual layer. However, the security status of the application layer cannot be ignored. The indexes are established based on the structure of IoT and the cloud computing which is center to IoT network.

- The whole system of IoT concerns certification, identification, privacy, protocols, standards and other issues. The appropriate authorities and industry organizations should consider these issues in a global perspective.

Thank you!